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Geology of the Oxford Lake-Carrot River Area

By J.J.M.W. Hubregtse

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Energy and Mines

Hon. Wilson D. Parasiuk
Minister

Dick Chenier
Deputy Minister

Geological Services
W. David McRitchie
Director

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Map GR83-1-5: Carghill Island 53L/13 ... In pocket
Map GR83-1-6: Oxford House 53L/14 ... In pocket
Map GR83-1-10: Windy Lake 53L/12 ... In pocket

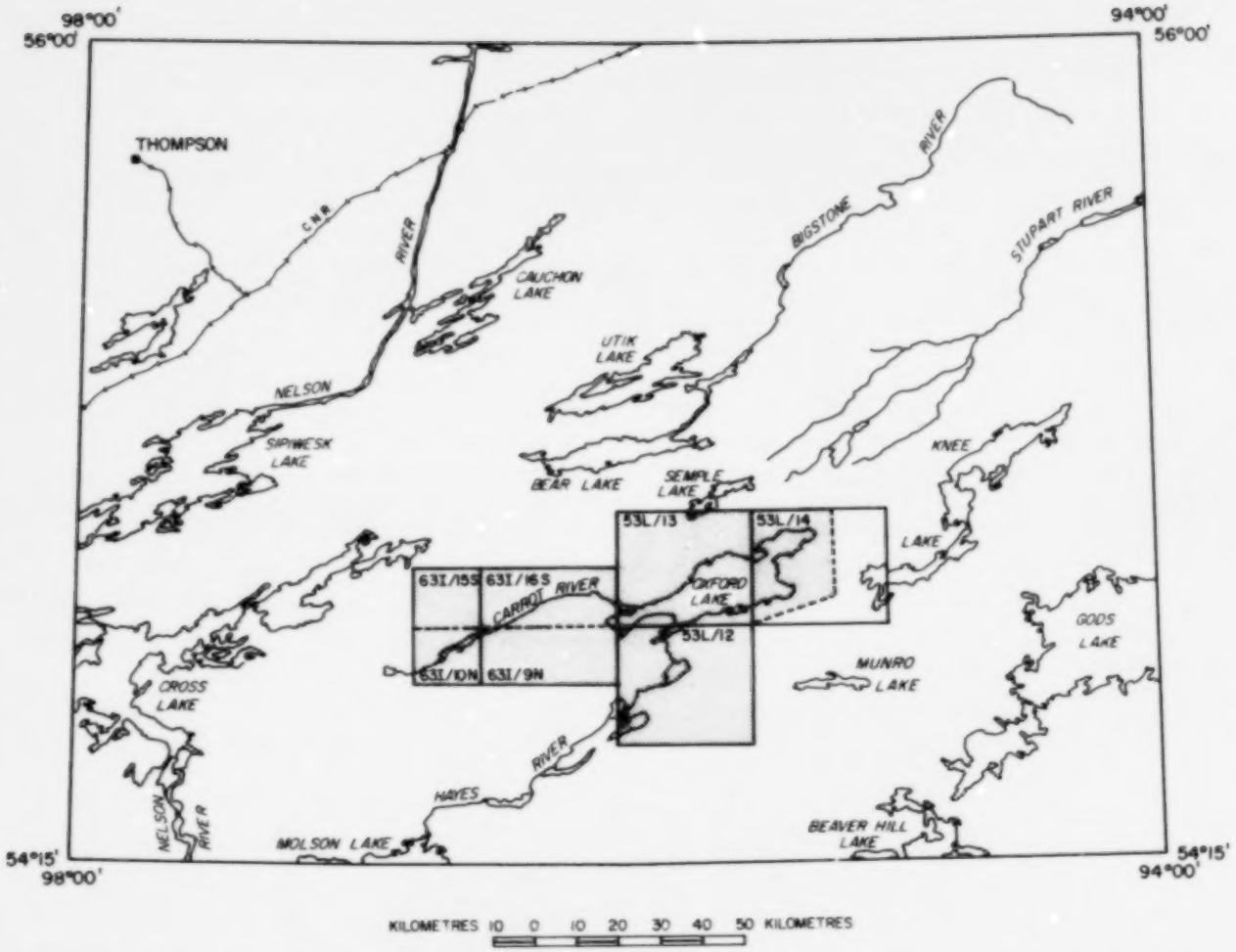


Figure 1: Project location map. Eastern half of 53L/14 (Oxford House) mapped by Gilbert (Publication GR83-1B, in prep.), see map GR83-1-6.

INTRODUCTION

Location and access

The Oxford Lake-Carrot River region is situated in east central Manitoba. Oxford House, the only settlement in the area, is located 185 kilometres east-southeast of Thompson. The area investigated comprises approximately 3000 square kilometres and is bounded by longitudes 95°12' and 96°40' and latitudes 55°00' and 54°30' (Fig. 1). The larger lakes and rivers in the region are Oxford Lake, Semple Lake, Windy Lake, Max Lake, Hayes River and Carrot River. The corresponding map sheets of the National Topographic Series are 53L/12, 53L/13, 53L/14, 63I/10, 63I/15 and 63I/16. The area is accessible by float plane from Thompson. The Oxford House community on the Oxford House Indian Reserve has an airstrip and is serviced on a regular basis. The waterways in the region can be navigated by canoe without much difficulty. It requires only two portages to travel to the western end of Carrot River. Hayes River can be navigated upstream into the Windy Lake-Max Lake area with interruptions only at Wipanipanis Falls and Moore Rapids just north of Windy Lake. Knee Lake can be reached by descending the Hayes River east of Oxford House. The major obstructions are Knife Rapids and Trout Falls.

Winter roads lead to Oxford House from Ilford, on the C.N.R., 124 kilometres to the north, and from Jenpeg near Cross Lake, 190 kilometres to the west.

Physical features and drainage

The Oxford Lake-Carrot River region is covered by glacial deposits of sand, clay and boulder clay. Glacial ridges, generally northeast-trending, are common, particularly in the area north of Oxford Lake, transecting a low and wet, swampy terrain. Ridges of bedrock are more prominent south of Carrot River and Oxford Lake. Topographic relief in the area is low. Some glacial ridges may stand out over 20 metres. Outcrop is mainly confined to shorelines. Scattered outcrops pierce through the glacial deposits in inland terrain. The regions northwest of Oxford Lake and south of Windy Lake have little or no bedrock exposed. Surficial deposits and features of the Oxford Lake area were mapped by Barry (1959).

The lakes and rivers of the Oxford Lake-Carrot River region are part of the Hayes River system which drains into Hudson Bay at York Factory. There are no control structures to interfere with the natural water flow.

Previous work

Geological descriptions of the area date back to 1877 (see Barry, 1959). The first significant geological research was published by Bruce (1919) and Wright (1926, 1932).

Bruce (1919) set out to map "a large basin of basic Precambrian rocks", underlying the headwaters of the Hayes River, after prospectors moved in and staked claims in the vicinity of Knee Lake. He recognized granite and quartz porphyries and an older Pre-granite Complex, that comprised a lower, dominantly sedimentary part and an upper, mainly volcanic part. Wright (1932) devised a more detailed table of formations. In contrast to Bruce he regarded the mainly volcanic part as the base of the volcano-sedimentary sequence. He introduced the terms "Hayes River lavas and sediments" and "Oxford sediments" for the volcanic lower part and the sedimentary upper part of the supracrustal sequence, respectively. He also recorded an unconformity between the two sequences. Wright's stratigraphic table has formed a starting point for all later investigations and, except for some modifications, has not been challenged substantially.

Barry (1959, 1960) divided the Hayes River Group into a lower and an upper unit. Many of the rocks assigned to the upper Hayes River Group unit by Barry (1959) have been assigned to the Oxford Lake Group in this report.

Present work and acknowledgements

This publication presents the results of work undertaken in the Oxford Lake-Carrot River region between 1973 and 1976 as part of the "Greenstones Project". Reports and maps of the Knee Lake, Gods Lake and Munro Lake area (Fig. 1) are by Gilbert (in prep.), Elbers (in prep.) and Marten (in prep.). Elbers (1976) discussed the hydrothermal mineralization of plutonic and volcanic rocks of the Greenstones Project and adjacent areas. The chemistry of the volcanic rocks of the Hayes River Group and the Oxford Lake Group has been described by Hubregtse (1976, 1978). A compilation of cancelled assessment files of exploration activities in the map-area has been published by Southard (1977). A review of the exploration history of the area up to 1960 can be found in Barry (1960). Preliminary maps and reports of the Oxford Lake-Carrot River region were published by Campbell (1971a, b), Campbell et al. (1972), Hubregtse and Gilbert (1973) and Hubregtse (1973a, b, c, d and 1974) during the course of the project, of which this contribution is the final report.

This report is accompanied by four geological maps at a scale of 1:50 000, and several supplementary maps and diagrams, all prepared by the Draughting Section of the Manitoba Mineral Resources Division. The geological maps correspond to the following NTS sheets.

Map	GR83-1-5:	Carghill Island	53L/13
	GR83-1-10:	Windy Lake	53L/12
	GR83-1-4:	Carrot River	63I/9 north half; 63I/10 north half 63I/15 south half; 63I/16 south half
	GR83-1-6:	Oxford House	53L/14

The eastern half of the Oxford House map sheet was mapped by H.P. Gilbert (in prep.).

The geology was mapped on a scale of one inch to one-half mile. Aerial photographs at a scale of one inch to one-half mile were used in the area east of 95°55' and photos at a scale of one inch to one-quarter mile were used in the area to the west.

Field work for this report was done during the summer of 1973. Excellent support in mapping was rendered by N.L.Green, Senior Assistant. L. Dzikowski's, D. Standberg's and D. Mehner's assistance was greatly appreciated. A brief visit was paid to the area in the summer of 1974. During this work the author was accompanied by B. Thompson-Jenbrysek and D. Hadad. Office work, including laboratory analyses, took place until 1976.

GENERAL GEOLOGY

Regional setting

The Oxford Lake-Carrot River greenstone belt is part of a generally east-trending network of belts of supracrustal rocks, that underlies much of northeastern Manitoba (Fig. 2) between the Berens batholithic belt (Ermanovics and Davison, 1976), the Nelson River and the Paleozoic strata of the Hudson Bay lowlands. Volcanic and sedimentary stratigraphic sequences, including the Hayes River Group and the Oxford Lake Group (as first recorded by Wright, 1928, 1932), have been documented in those belts that display lower metamorphic grades and less deformation, such as the Island Lake greenstone belt (Godard, 1963), the Cross Lake greenstone belt (Rousell, 1965) and the Oxford Lake-Knee Lake-Gods Lake greenstone belt (this report; Gilbert, in prep.). The narrower greenstone belts tend to be more deformed and/or more metamorphosed, and as a result stratigraphic relationships may have been obscured. Such greenstone belts underlie Carrot River, Max Lake (Hubregtse, 1974), Atik and Bear Lakes (Weber, 1974) and High Hill Lake (Weber, 1975).

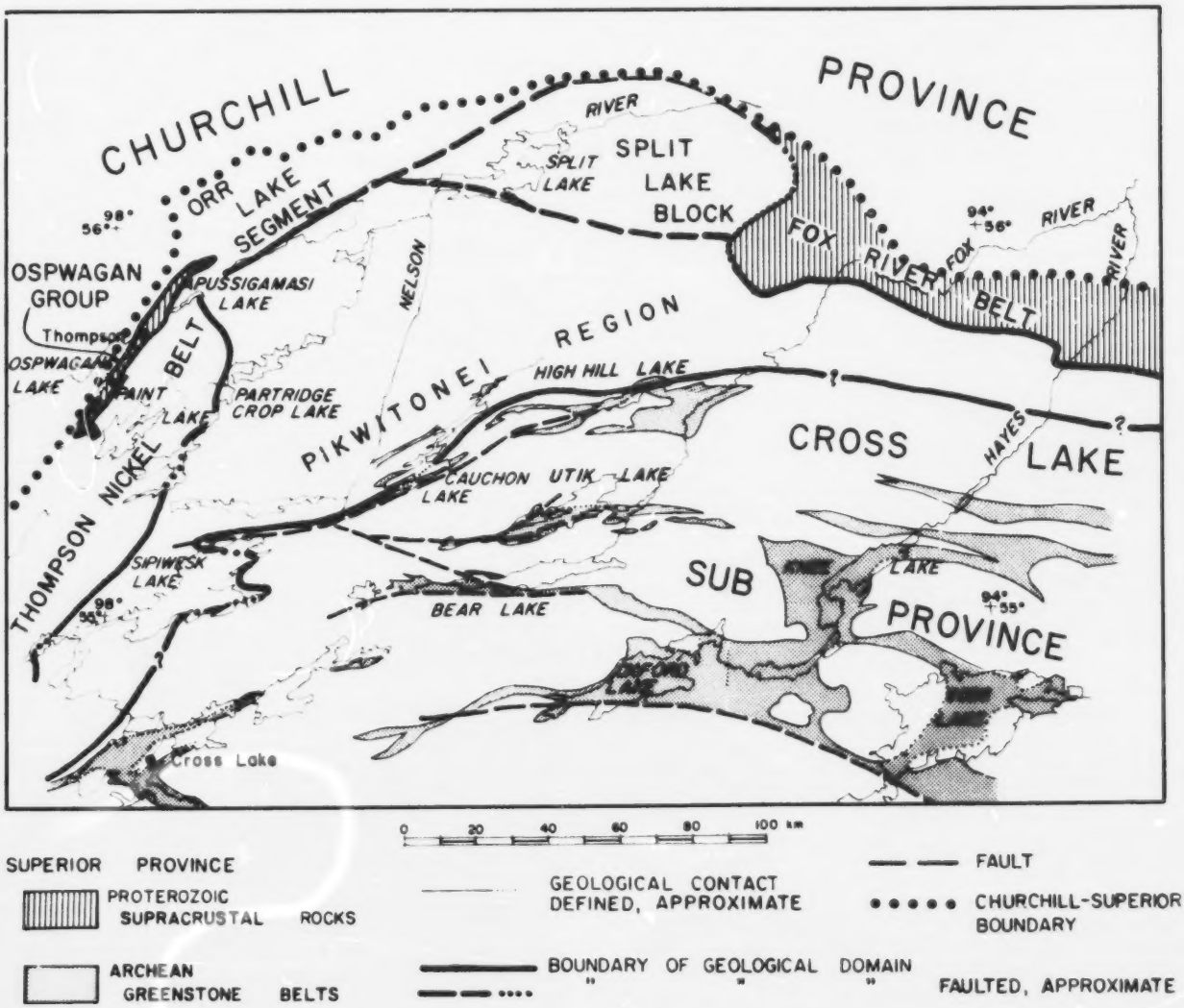


Figure 2: Major tectonic units of northeastern Manitoba (from Weber and Scoates, 1978).

The greenstone belts are surrounded by a plutonic-gneissic terrane that encompasses rocks of two age groups: plutonic rocks that predate and those that postdate the deposition of the sedimentary upper part of the supracrustal sequence (Oxford Lake Group). The name Bayly Lake Complex is introduced here for the plutonic, gneissic and volcanic rocks that postdate the Hayes River Group, but predate the Oxford Lake Group.

Whether the plutonic-gneissic terrane includes rocks that may have been a basement for the lower part of the supracrustal sequence (Hayes River Group) is a matter of contention.

Older sialic rocks must have existed prior to the deposition of the greenstone belts. Ages of 2900 Ma and 3000 Ma, for gneiss and meta-quartz diorite, have been reported by Krogh et al. (1974), from the Wanipigow-Bloodvein River area, 360 km south of the map-area. These rocks are part of the gneissic-plutonic complex that may be older than the greenstone belts, but it was not necessarily a basement for supracrustal rocks of the Island Lake-Gods Lake-Cross Lake area.

Stratigraphy, radiometric and relative ages

A condensed Table of Formations (Table 1) outlines the stratigraphy in the Oxford Lake and Carrot River greenstone belt. The oldest rocks are mafic rocks of the Hayes River Group (units 1, 2 and 3). No information about the base of the Hayes River Group is available since the lower sections of the Hayes River Group are intruded by tonalites and granites of units 4, 7 and 11. The lowest members of the south-facing monocline of the Hayes River Group are amphibolites derived from basalts and are exposed in the Wapaskosowakow Lake area. The lowest, best preserved member of the north-facing monocline of the Hayes River Group is an oxide iron formation, postdated by peridotite with possible flow characteristics, and overlain by pillowed basalt on High Rock Island. Since the tonalites of the Bayly Lake Complex are intrusive into the Hayes River Group tonalites, the peridotite and the iron formation on High Rock Island should not be regarded as the base of the Hayes River Group. Nevertheless, investigations in Archean greenstone belts of varying ages and geographical locations, have shown in general that ultramafic lavas tend to occur in the lower part of the greenstone belt successions.

A U-Pb age of 2 7 Ga (Catanzaro, unpublished) was determined for zircons from dacites (unit 2) of the Hayes River Group at Knee Lake (Gilbert, in prep.).

At Lynx Bay a sequence of intermediate and felsic pyroclastic and related sediments (unit 5) are entirely underlain and surrounded by plutonic rocks of unit 4 from which they are derived. The emplacement of the members of units 4, 5, 6 and 7 of the Bayly Lake Complex is thought to have taken place mainly after, but also possibly during, the deposition of the Hayes River Group.

Oxford Lake Group sediments are erosion products derived from the previously tectonized rocks of the Hayes River Group and Bayly Lake Complex. The Hayes River Group directly underlying the Oxford Lake Group commonly comprises pillowed basalts. The sedimentary component of the Hayes River Group is negligible in the map-area, in contrast to Island Lake (Godard, 1963) and Cross Lake (Rousell, 1965). However, sediments may have been an important component of the higher levels of the Hayes River Group at Oxford Lake, before erosion, since greywacke clasts are commonly encountered in the Oxford Lake Group basal conglomerate (unit 9).

A Rb-Sr whole rock age of 2 64 + 0 12 Ga (Brooks, et al., 1982) was obtained for the lower mafic volcanic members of the Oxford Lake Group (unit 8). Since the deposition of the volcanic and sedimentary members of the Oxford Lake Group was continuous and not interrupted by major events, an Archean age is assumed for the upper sedimentary members of the Oxford Lake Group (unit 10).

TABLE 1
Table of Formations — Oxford Lake-Carrot River Area

PLEISTOCENE DEPOSITS				
great unconformity				
INTRUSIVE ROCKS	13	—	diabase, gabbro, olivine norite	
	12	—	diabase, gabbro	
	11	—	granodiorite	
intrusive contact				
OXFORD LAKE GROUP	10	—	greywacke, arkosic wacke, arenite, argillite, minor iron formation	
	9	—	conglomerate	
	8	—	volcanogenic sediments; porphyritic volcanic rocks, flows and pyroclastic deposits (absarokite, shoshonite, andesite, dacite and rhyolite)	
unconformity				
BAYLY LAKE COMPLEX	7	—	tonalite, granodiorite and granite	
	6	—	tonalitic gneiss, gabbro	
	5	—	quartz wacke, conglomerate; intermediate and felsic pyroclastic deposits	Lynx Bay assemblage
	4	—	porphyritic tonalite, tonalite, granodiorite, minor granite	
HAYES RIVER GROUP	3	—	volcanogenic greywacke and minor conglomerate; iron formation	
	2	—	rhyolite and dacite; flows and pyroclastic deposits	
	1	—	dolerite, mesocratic porphyry, porphyritic gabbro; basalt, mainly pillowed; peridotite and melanogabbro, sills and rare flows	

The intrusive rocks that postdate the Oxford Lake Group yield ages straddling the Archean/Aphebian boundary. The Semple River and Magill Lake intrusions both lie within and apparently intrude the Oxford Lake Group. A Rb-Sr whole rock age of 2457 Ma + 34 (^{87}Sr = 1.42 x 10^{11}yr - 1) (Clark and Cheung, 1980; Gilbert, in press) was obtained from the late tectonic Magill Lake granite and accordingly a minimum age of 2.46 Ga can be inferred for the early to syntectonic Semple River granodiorite (unit 11). Gabbros of unit 12 are tectonized and metamorphosed and likely belong to the same age group.

Diabases and gabbros (unit 13) of the Molson dyke swarm (Scoates and Macek, 1978) are not affected by Kenoran metamorphism and deformation. An Aphebian age for these dykes has been suggested (Hubregtse, 1978).

Classification

All rocks and rock units described in this report are metamorphosed with the exception of rocks of unit 13. However, the prefix "meta" and the adjective "metamorphosed" have been used sparingly in the text.

Pyroclastic rocks are subdivided according to fragment size after Fisher (1966). Plutonic rocks are classified following Streckeisen (1976).

Grain sizes are classified as follows:

very coarse grained:	larger than 3 cm
coarse grained:	5 mm - 3 cm
medium grained:	1 mm - 5 mm
fine grained:	0.33 mm - 1 mm
aphanitic:	smaller than 0.33 mm

THE HAYES RIVER GROUP (UNITS 1, 2 & 3)

Stratigraphy

The oldest rocks recognized in the Oxford Lake-Carrot River greenstone belt belong to the Hayes River Group, which was documented over the entire width of the map-area, from Back Lake to the west end of the Carrot River. The Hayes River Group comprises all volcanogenic rocks, effusive, pyroclastic, hypabyssal and epiclastic in nature, that predate the plutonic and gneissic rocks of the Bayly Lake Complex. The composition of the Hayes River Group may vary from ultramafic to felsic, but basalts are most common. Faults and plutonic rocks segment the Oxford Lake-Carrot River greenstone belt into four parts. The Hayes River Group reaches its greatest width in central Oxford Lake. Along the Carrot River the greenstone belt is intruded by younger tonalitic plutons at 96°24'. Around Carrot Bay, younger granites, porphyries and dacitic pyroclastics separate the major part of the Oxford Lake belt from the Carrot River belt. Another discontinuity in the Hayes River Group exists between Semple Bay and Oxford House where sediments of the Oxford Lake Group overlie the Hayes River Group. Younger granites intrude both the Hayes River Group and the Oxford Lake Group in this area.

WESTERN AND CENTRAL OXFORD LAKE

The Hayes River Group constitutes a south-facing monocline of maximum 11 km width in northern Oxford Lake. The true width remains unknown as younger granites intrude the lower stratigraphic levels. A prominent east-trending fault, sub-parallel to the stratigraphy, bounds the monocline on Carghill Island and to the west.

A much thinner sequence of Hayes River Group rocks, mapped in the High Rock Island and Cat Eye Bay area (southern Oxford Lake), faces north and is intruded by younger plutons of tonalitic composition.

The Hayes River Group is mainly comprised of pillowed and massive basalts, intravolcanic mafic sills and minor felsic pyroclastics and flows. The Hayes River Group constitutes several volcano-sedimentary cycles in the Knee Lake area (Elbers, in prep.: Hubregtse, 1976, 1978). In general, a cycle is defined by a thick basaltic lower portion and a much thinner felsic and sedimentary upper portion. Volcano-sedimentary cycles are less obvious in the Oxford Lake area, where felsic horizons are scanty.

Figure 3 displays the Hayes River Group sequence in the Carghill Channel-Kwaykwaychi Bay-Semple Bay-Kanawastiwiwin Island region.

The Hayes River Group is subdivided into:

a) an upper sequence of dominantly pillowed basalt (underlying most of Carghill Island);
b) a lower sequence comprising mainly porphyritic flows, pyroclastic deposits and intravolcanic mafic sills.

The boundary between both sections runs just north of Carghill Island.

Basaltic to andesitic porphyritic flows (1c), the lowest well-exposed members of the Hayes River Group, were mapped along Carghill Channel over a strike length of 16 km. Massive flows alternate with pillowed flows. Porphyritic pillow basalt breccia (1c3) was mapped east of Kwaykwaychi Bay. The porphyritic basalts and andesites are locally intercalated with mafic greywacke layers and sporadic intraformational monomictic conglomerates (3d) containing gabbroic cobbles.

Pyroclastic deposits of mafic- to intermediate and intermediate- to acid composition (1f, 2b) are intimately associated with the porphyritic flows. The porphyritic flows and the porphyritic fragments of the pyroclastic deposits have the same parentage.

Intravolcanic gabbroic sills (1e) account for the largest part of the lower section of the Hayes River Group. The sill rocks display a variety of grain sizes and textures. Most of the rocks have hypabyssal characteristics. Granophyric differentiates are common.

Thick monotonous units of non-porphyritic massive, pillowed and variolitic basalts make up most of the upper Hayes River Group; pillow breccia occurs locally. Felsic units (unit 2) are scarce. Massive rhyolite flows and sills and dacitic pyrobreccias were documented in Carghill Channel and Semple Bay. Intravolcanic mafic sills are much less abundant in the upper section.

Layers of conspicuous very coarse grained basalt were mapped as part of the upper section. These megaphyric basalts (1d), are associated with plagiophyric dolerite (1e3). The higher levels of the upper section comprise non-variolitic basalt.

Iron formation (unit 2c) is rarely found in the monoclinal sequence that underlies the northern part of Oxford Lake. A prominent layer of oxide facies iron formation was traced over a strike length of 2 km near High Rock Island in the southern monocline. This iron formation is partially assimilated by ultramafic rocks. Oxide and sulphide facies iron formation occurs along strike on the southern shore of Cat Eye Bay.

Ultramafic rocks (unit 1a) are scarce. Two thin sills are located in Carghill Channel and other bodies occur at High Rock Island and in Lynx Bay. Their position within the Hayes River Group is ambiguous. On Bleak Island the peridotite sills cut the gabbroic intravolcanic sill. On High Rock Island in southwestern Oxford Lake a 2.9 km long peridotite layer has both flow and sill characteristics, with slight differentiation towards a hornblenditic composition. The ultramafic rock exposed on the small island east of High Rock Island is perhaps a volcanic or subvolcanic phase, as it exhibits spinifex quench textures. The peridotite contains xenoliths of oxide facies iron formation and is overlain by pillowed basalt. Strikingly similar relationships were documented at Peridotite Island in Wakahoo Lake and on western Carrot River. Thus, the ultramafic rocks seems to have been emplaced after a period of quiescence during the initial phase of a new eruptive cycle.

CARROT RIVER

A discontinuous narrow belt of Hayes River Group rocks underlies Carrot River. It is intruded by younger tonalitic rocks (4) at 96°24', which divide the belt into eastern and western portions.

Basalt is the major component but rhyolitic and dacitic flows and pyroclastic deposits, and ultramafic sills are also important constituents, particularly in the eastern part of the belt.

Deformation has obliterated most of the primary structures. The few preserved pillow structures exhibit north-facing tops. Basalts and intravolcanic gabbros (unit 1) which occupy the southern margin and centre of the belt are overlain by felsic pyroclastic deposits and rhyolite flows (unit 2a) along the northern margin.

Sedimentary rocks are rare. Iron formation (2c) is in contact with an ultramafic sill (1a) at the west end of Peridotite Island. Iron formations (mostly oxide facies) are better exposed in the western part of Carrot River, where they can be traced over 3.1 km. Another out-

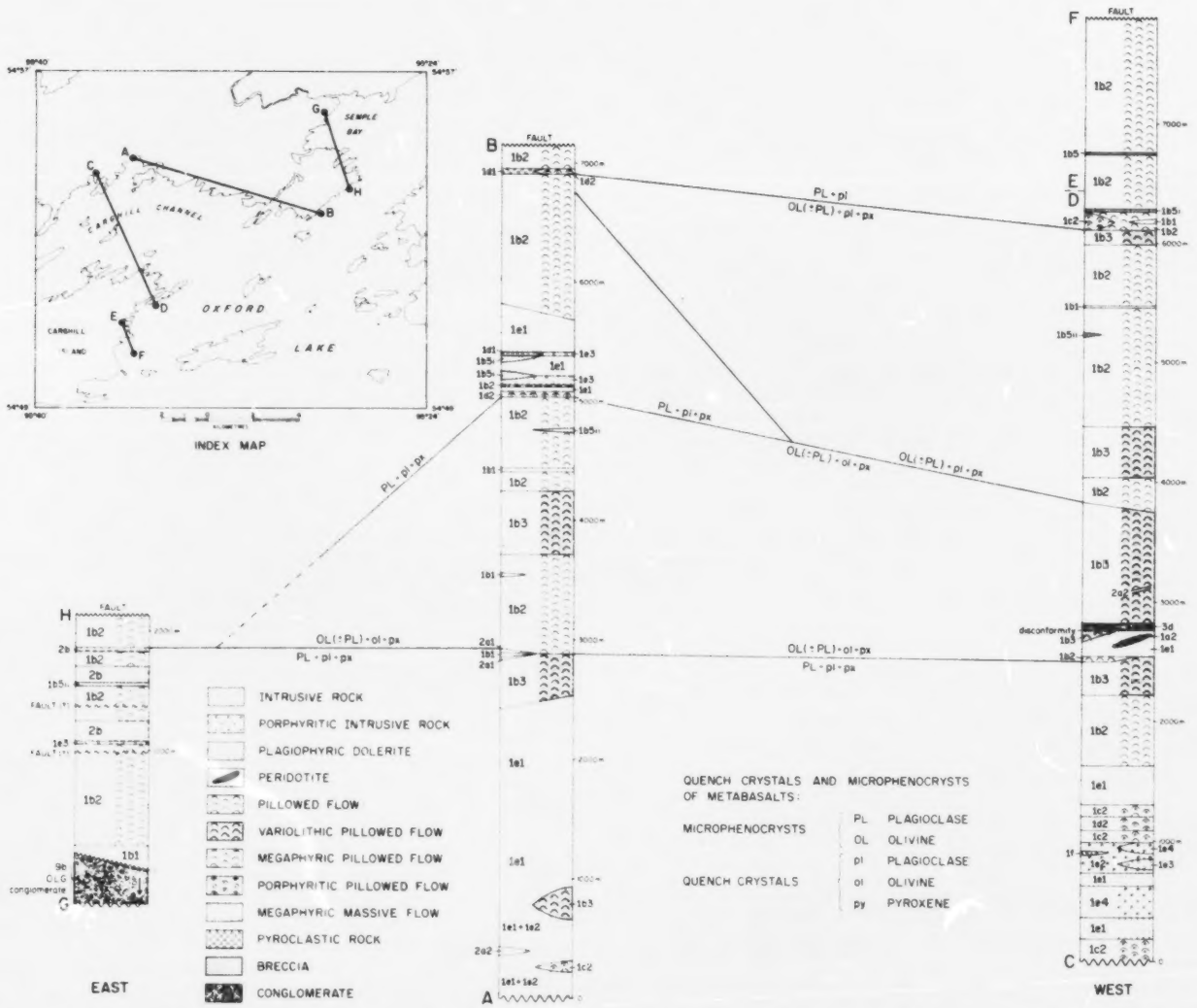


Figure 3: Restored stratigraphic columns of the Hayes River Group in the Oxford Lake area. Lithologic unit numbers as on geological maps GR83-1-1 to 14.

crop, 5.8 km along strike at the extreme west end of the river, probably represents the same layer. An east-trending ultramafic sill was mapped 7.4 km along strike of the iron formation. Thus, there is a consistent association of ultramafic rocks and iron formation similar to that of High Rock Island.

The Carrot River belt resembles the southern monocline of the Oxford Lake belt. Both are north-facing, have approximately the same width with similar stratigraphic sequences suggesting that the southern limb of the Oxford Lake belt is the eastern extension of the Carrot River belt.

NORTHEASTERN OXFORD LAKE

The northwest-striking, south-facing Hayes River Group is poorly exposed in this area. The rocks are similar to those at central Oxford Lake but the grade of metamorphism is generally higher.

Amphibolitic metabasalt with poorly preserved pillow structures (unit 1b) occurs northeast of Stubbs Lake and a metagabbroic sill (unit 1e) with preserved granophyric texture is located at Stubbs Lake.

At the south shore of Stubbs Lake a 600 metre wide zone of dominantly felsic volcanics (unit 2a) was mapped comprising a lower layer of porphyritic dacite, overlain by a sequence of alternating mafic and felsic rocks. Individual layers may be as narrow as 50 cm. During shearing the felsic layers were brecciated and boudins of mafic layers were rotated (Fig. 4) indicating a right-lateral movement.

The Hayes River Group can be traced farther east towards Knee Lake (Gilbert, in prep.). Between Stubbs Lake and Knee Lake exposure is poor but continuity is indicated by the aeromagnetic pattern. The aeromagnetic trend is offset right-laterally along northeast-trending breaks approximately 1.5 km southeast of Stubbs Lake and near Fores-

Figure 4: Boudinaged and partially rotated amphibolite layer (unit 1h) in metadacite (unit 2a1); south of Stubbs Lake.

try Point. The right-lateral displacements are a result of late block faulting which is common in the Oxford Lake and Carrot River region. The same relationship between older, generally east-trending shears and younger northeast-striking faults is apparent on outcrop scale.

The only exposure of the Hayes River Group between Oxford Lake and Knee Lake occurs in a zone of scattered outcrop between Forestry Point and Kawapiskachowasik Rapids. The most significant and conspicuous rock is a megaphyric basalt (1d). Plagioclase phenocrysts up to 6 cm are stretched and give the rock a streaky appearance. Other rock types include sheared pillow basalts (2b2) and variolitic pillow basalts (2b3). Porphyritic dykes are common in this area. They are offshoots of the granodiorite (7) that underlies northern Black Lake.

Petrography

UNIT 1: METAMORPHOSED MAFIC VOLCANIC AND RELATED SUBVOLCANIC ROCKS; MINOR ULTRAMAFIC ROCKS; MINOR SEDIMENTARY ROCKS

Ultramafic rocks (1a)

Ultramafic rocks with spinifex texture (1a1)

Serpentinized peridotite (1a2)

Ultramafic rocks of uncertain age (1a3)

Melanogabbro, hornblendite (1a4)

DISTRIBUTION

Ten occurrences of ultramafic rocks were mapped in the Oxford Lake-Carrot River greenstone belt. Small ultramafic sills were documented on Bleak Island, at 96°7'W, 96°19'W, 96°31'W, 96°34'W and 96°39'W, respectively. Several reefs of ultramafic rock occur in southern and eastern Lynx Bay. Two prominent ultramafic layers were mapped near High Rock Island and Peridotite Island (Wakahoo Lake) over strike lengths of 2.9 km and 8.3 km, respectively.

Peridotite Island

The largest ultramafic sill (up to 250 m thick) is exposed along the southern shore of Peridotite Island. There is some differentiation within the sill towards hornblenditic composition. The east end of the body has a mylonitized contact with a younger granite pluton (unit 7e), the contact zone consisting of fine grained siliceous mylonites and talc schists. The western extension of the sill is a thin, brecciated and carbonate-rich serpentinite layer (less than 50 m thick). The sill intrudes metamorphosed banded iron formation at the west end of Peridotite Island and, in turn, is intruded by metagabbro (unit 1e). Chilled gabbro margins are exposed on two islands south of the eastern tip of Peridotite Island. Plagiophyric dolerite (unit 1e3) underlies the sill at the western tip of Peridotite Island, and similar plagiophyric rocks overlie the sill at the east end. Younger gabbro and olivine-norite dykes of the Molson swarm (13) cut the ultramafic rocks at the west tip and south of the east end of Peridotite Island, respectively.

The coincidental occurrence of plagiophyric dolerite, an ultramafic sill and younger pyroxene- and olivine-bearing diabase on both ends of Peridotite Island led Barry (1959) to "incorporate" these rocks of different ages into one differentiated layered sill, occupying the southern half of the island. Traverses across the island, however, did not reveal a large-scale layered sill structure. Instead, the younger diabase was traced farther inland at the west end, suggesting that this diabase is cross-cutting and probably part of unit 13. Fine grained metabasalts and metagabbros underlie the central and eastern part of the island.

Davidson (1974) considered the ultramafic complex at Peridotite Island to be emplaced in subhorizontal position. He suggests that the magma fractionated into dunite and melanogabbro, and that water was extracted from the country rock during an early process of serpentinization. This view is supported by the presence of unusually "dry" clinopyroxene amphibole-bearing quartzofeldspathic gneisses at the contact of an ultramafic body 6 km southeast of Peridotite Island at 96°19'W. The origin of the felsic rocks is unclear, but they are believed to be metadacites, as the rocks are fine grained and contain some relicts of feldspar phenocrysts. Clinopyroxene is normally absent in felsic rocks of the Oxford Lake-Carrot River area. In the metadacite, however, it forms randomly oriented aggregates with a prismatic colourless amphibole and its presence is attributed to the removal of H_2O and possibly also contact metamorphism caused by the ultramafic sill. Davidson (1974) assumed that the nickel sulphides in the ultramafic rocks are the result of sulphurization, with the sulphur being derived from the sulphide-bearing volcanics that form the country rock.

High Rock Island

The ultramafic rocks on High Rock Island display rare spinifex and cumulate textures (1a1). Random, feathered crystallites, up to 4 cm in length, define a spinifex texture indicating either extrusion or intrusion of the peridotites at a very shallow level.

In thin section the spinifex crystallites consist of elongate aggregates of chlorite, and green and colourless amphibolites. Ilmenite with rims of sphene, and other opaque minerals occur throughout the rock.

The geological setting of this ultramafic body is strikingly similar to that of the Peridotite Island body. At High Rock Island the

ultramafic rocks are also in contact with an iron formation and are overlain by basalt.

Carrot River

A discontinuous peridotite layer was documented at 96°19'W along the north shore of Wakahoo Lake (Carrot River) over a strike length of approximately 1.4 km. Barry (1959) interpreted the layer as a crescent-shaped intrusion, but foliation directions within the metaperidotite define a large S-shaped drag fold. The volcanic and subvolcanic rocks that underlie the western shore of the small bay are strongly deformed with well developed lineations plunging moderately towards the southwest. These relatively late structural elements are only rarely developed in the Oxford Lake-Carrot River greenstone belt. They are associated with late left-lateral faults and drag folds (see Structure).

Lynx Bay

Several reefs and smaller islands in Lynx Bay are underlain by ultramafic rocks (1a3). Where contacts are exposed, the ultramafics are always fault-bounded against the surrounding tonalitic rocks of units 4 and 5. The composition is mainly dunitic, but ranges to peridotitic. Serpentine-coated shear zones and slickensides, particularly in the metaperidotites near the east shore of Lynx Bay, indicate that the ultramafic bodies were affected by northeast-trending left-lateral shearing (see Structure). The ultramafic rocks, however, also display an older, east-trending foliation which is conformable with the structural trend of the Hayes River Group.

It is unclear whether the ultramafic rocks in Lynx Bay are part of the Hayes River Group or are younger. It is conceivable that the Lynx Bay ultramafics and the High Rock Island peridotite are part of a single ultramafic body, which was segmented by left-lateral fault movements.

PETROGRAPHY

Metaperidotites are distinguished by their black-blue fresh colour. Red, brown, green and even white colours may characterize the usually rough, weathered surface. Green and terracotta coloured serpentinite minerals have been observed on slickensides. Asbestos and (less common) carbonate veinlets cut the rock in various directions. Magnetite-asbestos-carbonate veins occur on High Rock island.

Metadunites (serpentinized dunites) have an olive-green coloured weathered surface. Cumulate textures of olivine, up to 2 cm, are readily visible on glacially polished coarse grained outcrops in Lynx Bay (Fig. 5).

The metaperidotites may grade into dark green to black, dense, fine- to coarse-grained hornblende peridotite, hornblendite and melanogabbro (1a4) with a higher lustre.

In thin section, the original mineralogy of the metaperidotites is, in general, completely replaced by chlorite, iddingsite, bowlingite, colourless amphibole, talc, carbonate and opaque and serpentine minerals. The original olivine is preserved only in unaltered portions of the peridotite at the west end of Peridotite Island. Several stages of olivine breakdown are preserved. The olivines exhibit a dusty appearance but retain their optical properties, prior to being replaced by brown, near isotropic bowlingite. The outlines of the original olivine crystals are still visible after complete serpentinization, commonly exhibiting the typical "mesh" texture. Colourless amphibole (actinolite?), riddled with opaque minerals, grew after pyroxene. Bastite textures, pseudomorphic after orthopyroxene are common.

The ultramafic sill on Bleak Island contains dusty, pseudomorphic chlorite aggregates, which exhibit a peculiar blue-orange pleochroism. The X-ray pattern and the optical properties closely match the characteristics of a chrome-chlorite (J. Macek, pers. comm.), perhaps kochubeiite or kammererite.

The hornblendites consist mainly of hornblende, chlorite and opaque minerals and minor sphene. They may contain oval-shaped chlorite aggregates, possibly pseudomorphic after olivine.

ASSIMILATION OF IRON FORMATION

Evidence from a small island, east of High Rock Island suggests that some hornblendites were locally formed from peridotite by assimilation of silica-rich iron formation and not by igneous differentiation. The outcrop shows a crudely layered repetition of peridotite and iron formation separated by hornblendite. Three levels of layered iron formation were recognized in the metaperidotite. The hornblendite layers vary in width and their contacts with the peridotite are vague and gradational. The contact zone between the non-assimilated part of the iron formation and the hornblendite consists of "hornblenditized" iron formation, in which only the well-preserved delicate magnetite layers of the original iron formation show up as ghost structures. The silica-rich layers of the assimilated iron formation, however, are completely replaced by amphibole and serpentine minerals.

Basalt, minor andesite, related sills, minor basic tuff (1b)

Massive basalt, minor andesite (1b1)

Pillowed basalt, minor andesite (1b2)

Variolitic pillowed basalt, minor andesite (1b3)

Amygdaloidal pillowed basalt and andesite (1b4)

The usually fine grained aphyric metabasalt varies in colour from grey, green, brown-green to black. Rare meta-andesites are difficult to distinguish from metabasalts in outcrop, but in thin section they contain abundant plagioclase microphenocrysts (see below).

PILLOWS AND VARIOLES

Pillows commonly exhibit concentrically zoned colour variations, particularly in variolitic metabasalts (1b3). Varioles are frequently arranged in a concentric fashion: a glassy outer selvage, an inner variole-free selvage approximately 10 cm in width, a variole-rich zone, approximately 10 cm in width, in which the white varioles "float" freely in a grey-green matrix and a central zone where varioles coalesce. Varioles average about 1 cm in size, but may be as large as 3 cm. Rare vugs in pillows are filled with quartz and carbonate. Small quartz-epidote- carbonate-filled vesicles occur sporadically (Fig. 6).

Pillows range in length normally from 1 - 6 m. The length-width ratio generally varies between 6:1 and 3:1; it may be considerably higher in areas of strong tectonic flattening.

Introduction of volatiles into the metabasalts resulted in the formation of lenses, pods and stringers of carbonate, and led to widespread obliteration of primary microscopic features.

A microscopic examination shows that delicate, primary textural and mineralogical features are only preserved in areas that were weakly affected by deformation and metamorphism, such as eastern Carghill Island and the peninsula south of Semple Bay. Although the original mineral assemblages are replaced and overgrown by metamorphic minerals, many basaltic flows still show devitrified glassy zones, primary microphenocrysts and quench textures indicative of fast cooling.

Figure 7 shows part of a pillow selvage with curved perlitic cracks enclosing domains of reconstituted(?) glass. The centres of these domains are composed of chlorite commonly riddled with aphanitic needles and sericite flakes. The chlorite centres are surrounded by radial aggregates of euhedral epidote, which developed along the perlitic cracks. The radial growth of epidote and the presence of carbonate porphyroblasts in the chlorite centres suggests introduction of calcium and carbon dioxide along the perlitic fractures. Other features that confirm migration of material are palimpsest rusty brown zones parallel to the perlitic cracks now overgrown by the epidote aggregates.

Pillow cores and selvages are characterized by contrasting amounts of calcium: either a calcium-rich rim and a calcium-poor core

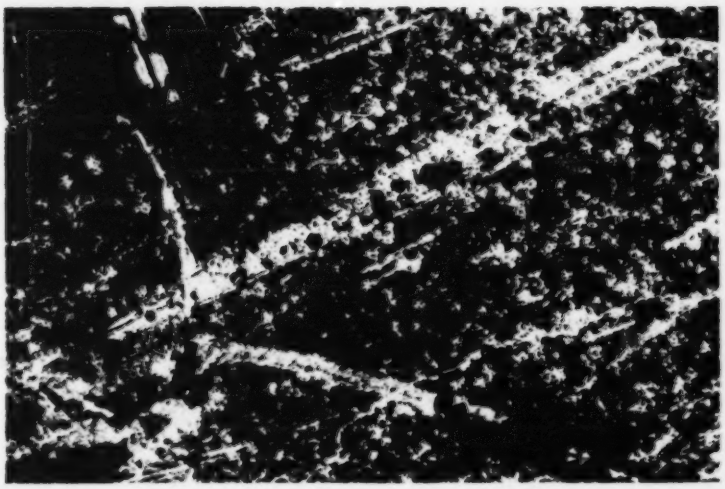


Figure 5:
Serpentinized dunite (unit 1a3); eastern Lynx Bay.

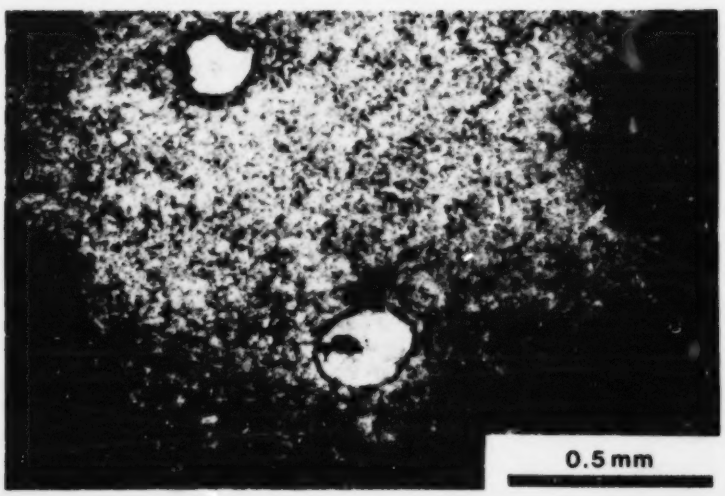


Figure 6:
Varioles and quartz- epidote- carbonate-filled vesicles in pillow basalt (unit 1b3) from Carghill Channel.

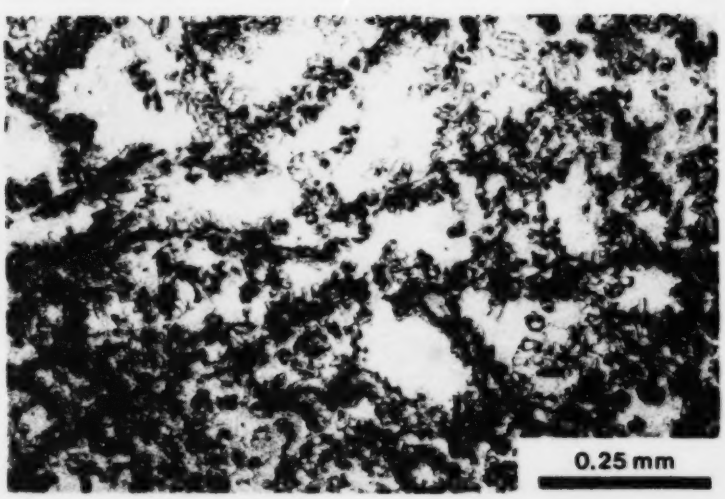


Figure 7:
Perlitic cracks in pillow selvage in basalt (unit 1b2) from Carghill Channel. The high-relief aggregates consist mainly of epidote. The clear areas contain chlorite.

or a calcium-poor rim and a calcium-rich core. According to Vallance (1965, 1969) re-distribution of chemical components can take place during devitrification, hydrothermal activity, diagenesis or low-grade burial metamorphism.

Under the microscope varioles show up as greyish patches in a grey-green matrix. The matrix colour ranges from grey to green with increasing grade of metamorphism, depending on the amphibole colour. Epidote is mainly concentrated in the varioles and amphibole is dominantly in the matrix.

QUENCH CRYSTALS AND MICROPHENOCRYSTS

Pseudomorphed quenched phases in basalt flows are well preserved in the Semple Bay-Carghill Island area. Bryan (1972a, b) and Muir and Tilley (1966) have described quench crystals in modern submarine basalts. Quench textures have also been reported from other Archean terrains (Gélinas and Brooks, 1974; Pearce, 1974). For this report, the original nature of the quench textures was identified by visual comparison with the textural features reported from modern basalts. Quench crystals have an irregular and imperfect shape and are often curved and strongly elongated in one or two directions. In contrast, microphenocrysts are regularly shaped, and not bent. Their minimum dimensions are approximately 0.04 x 0.15 mm and they cannot be identified by the unaided eye. It is assumed that the microphenocrysts were carried in suspension during extrusion, in contrast to the quench phases that were formed at the time of rapid cooling on the surface.

Plagioclase is a common quenched phase in the metabasalts of Oxford Lake. It occurs as strongly elongated originally hollow crystals, with swallow tail terminations. Bryan (1972a) reports the a-axis as the elongation axis of plagioclase microphenocrysts from recent basalts. When cut perpendicular to a, the plagioclase appears as "belt buckles" (Fig. 8). Plagioclase needles, present in the varioles as well as the matrix, average 0.5 mm, but may be as long as 0.8 mm. The average thickness is 0.02 mm. The pilotaxitic fabric is overgrown by the chlorite-amphibole-epidote assemblage. The plagioclase needles show up as clear streaks in the otherwise clouded mass.

Plagioclase microphenocrysts may form cross-type intergrowths (Fig. 9), and display albite twinning. A pillowed basalt at the northern shore of Carghill Channel, due north of Kanawastiwiwin Island, contains unusually fresh plagioclase crystals that seem to have retained their original composition. The plagioclase microphenocrysts display albite twinning and are only rarely partially replaced by

Figure 8:
"Belt buckle" plagioclase in quenched basalt from Carghill Channel.

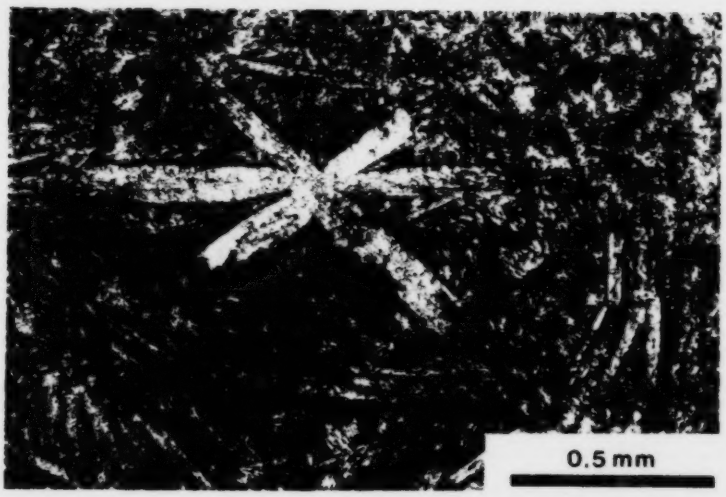


Figure 9:
Cross-type intergrowth of plagioclase micro-phenocrysts in basalt from Carghill Channel.

some clinozoisite. Interstitial spaces are filled with feathery aggregates of faint green amphibole ($\gamma\Lambda c = 15°$[1], $\delta = 0.014$[2]) pseudomorphic after quench pyroxene. The groundmass contains pale green, unstrained and clear chlorite, clouded clinozoisite, leucoxene, carbonate and mosaics of quartz. The anorthite content in the microphenocrysts ranges from 65 to 80%, assuming that the plagioclase has low-temperature optics. In the event that high-temperature optics were retained the anorthite contents would range from 54 to 71%. Microphenocrysts with high anorthite contents were also detected in a weakly variolitic andesite, mapped in the same area. Plagioclase microphenocrysts are well twinned according to the albite law. Anorthite contents range from 34 to 42% or 26 to 34% depending on high-temperature or low-temperature optics, respectively. The presence of labradorite reflects the low grade of metamorphism that affected this part of the Oxford Lake area.

Another indication of low grade metamorphism in this particular area is the preservation of primary ilmenite in basalts. Ilmenite grains are rimmed by sphene and have a halo of leucoxene. Normally, metamorphism causes retrogression of the ilmenite-sphene association to leucoxene.

[1] $\gamma\Lambda c$: extinction angle between largest indicatrix and longest crystallographic axis

[2] δ : Birefringence

Feathery aggregates of amphibole are common in most flows. They resemble the sheaf-like and plumose clinopyroxene aggregates as reported by Muir and Tilley (1966) and Bryan (1972a, b). Quench pyroxene is rarely found in varioles. Plumose amphiboles may form rosettes (Fig. 10), embracing a spread of extinction angles up to 160°. Pyroxene is the most common quenched phase in Hayes River Group basalts and only some questionable pseudomorphosed pyroxene microphenocrysts were documented. Quench pyroxene is almost invariably accompanied by pseudomorphosed microphenocrysts of olivine and/or plagioclase. This indicates that pyroxene is always late in the crystallization sequence, which was also reported for modern basalts from the mid-Atlantic ridge by Muir and Tilley (1966) and Miyashiro et al. (1970).

Olivines occur in the matrix and the varioles as lantern-shaped microphenocrysts (Fig. 11) as reported by Bryan (1972a, b) from modern ocean floor basalts. They are replaced by aggregates of quartz, epidote and carbonate. If the microphenocrysts are replaced solely by quartz, they resemble double terminated quartz phenocrysts.

Other features that resemble quench textures are aphanitic needle-shaped skeletal aggregates replaced by a high-relief phase,

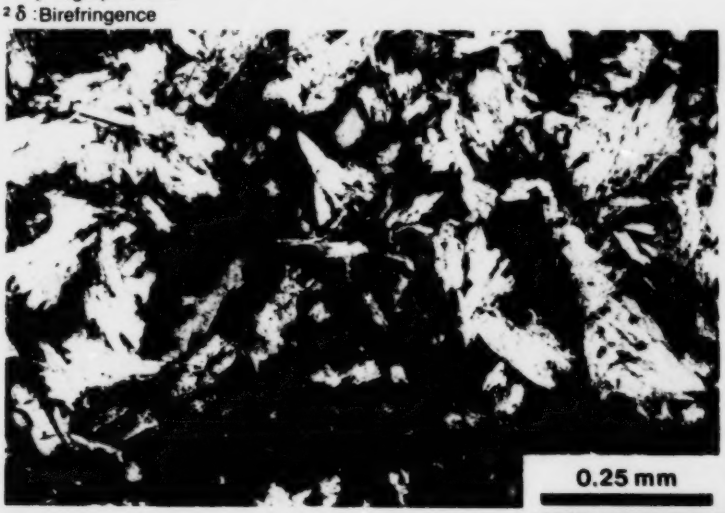


Figure 10:
Sheaf- and rosette-like aggregates of feathery amphiboles after plumose quenched pyroxenes in basalt from Carghill Channel.

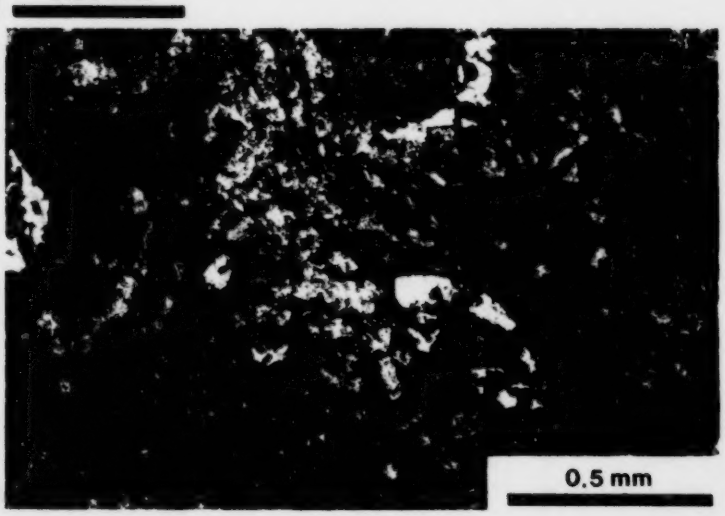


Figure 11:
Olivine microphenocrysts in basalt from Carghill Channel, replaced by aggregates of quartz, epidote, carbonate and opaques. Note the idiomorphic lantern shapes of the left-hand and lower right-hand pseudomorphs. The high-relief needle-shaped aggregates may represent chains of skeletal olivine.

possibly epidote (Figs. 11 & 12). The aggregates are not as dense as the quenched plagioclase. The randomly arranged needles have an average length of 1 mm and are solid, unlike quench plagioclase, and enclosed by amphibole aggregates, pseudomorphs after quench pyroxene. This texture is very similar to Bryan's (1972a, b) description of plumose pyroxene and chains of skeletal olivine. Figure 13 shows the latter texture. Aggregates of parallel blades up to 2 cm long and 0.15 mm wide occur randomly through the rock and are overgrown by chlorite and colourless amphibole. The centres of the needles contain sporadic trails of black opaque grains, representing excess iron and magnesium in the original olivine.

DISTRIBUTION OF MICROPHENOCRYSTS AND QUENCH TEXTURES; PETROGENETIC IMPLICATIONS

The regional distribution of recognizable pseudomorphosed quench crystals and microphenocrysts in the metabasalts is shown in Figures 3 and 14. It may not be an accurate record of the microphenocrysts and quench crystal assemblages in the metabasalts, since recognition is hampered (a) by an overprint of upper greenschist facies metamorphism in a zone parallel to Carghill Channel in the northern part, and (b) carbonate blastesis related to low-grade greenschist facies metamorphism near Kanawastiwiwin Island in the south. The zone in which quench phases and microphenocrysts were best preserved is characterized by a metamorphic assemblage that includes actinolite or colourless amphibole, chlorite, epidote, albite and quartz (see Metamorphism). Biotite and sericite may also be part of the paragenesis. Pseudomorphic quenched liquid phases are less likely to persist in carbonate and/or blue-green amphibole-bearing metabasalts.

Miyashiro et al. (1970) named modern abyssal tholeiites after the first mineral to crystallize, i.e., olivine tholeiites and plagioclase tholeiites. Pyroxene microphenocrysts are very rare in Hayes River Group metabasalts. A lack of pyroxene phenocrysts was also noticed in modern oceanic tholeiites (Muir and Tilley, 1966; Miyashiro, et al. 1970; Bryan, 1972).

Olivine tholeiites are abundant in the central part of the south-facing Hayes River Group sequence between Carghill Island and Semple Bay (Fig. 14). Plagioclase tholeiites occur along western and northern Carghill Channel, in the vicinity of Kistoteminakok Island and Semple Bay, and near Forestry Point. Olivine tholeiites and plagioclase tholeiites were documented at High Rock Island and the island west of Kisetpiskanak Island, respectively, in the north-facing monocline of the Hayes River Group.

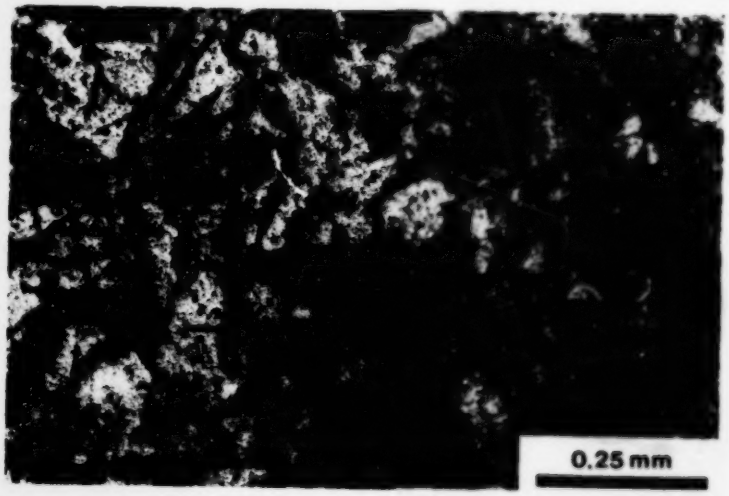


Figure 12:
Needle-shaped high-relief aggregates, possibly after chains of quenched olivine in amphibole groundmass after plumose pyroxene, in basalt from High Rock Island.

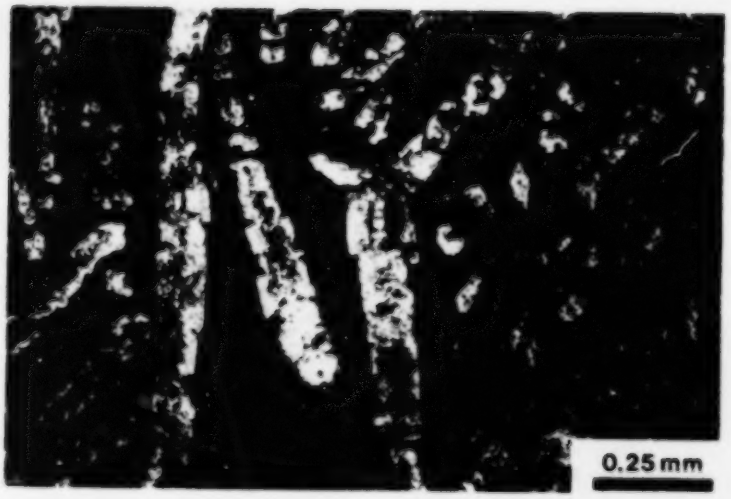


Figure 13:
Pseudomorphosed skeletal blades and microphenocrysts after olivine in basalt from Carghill Channel.

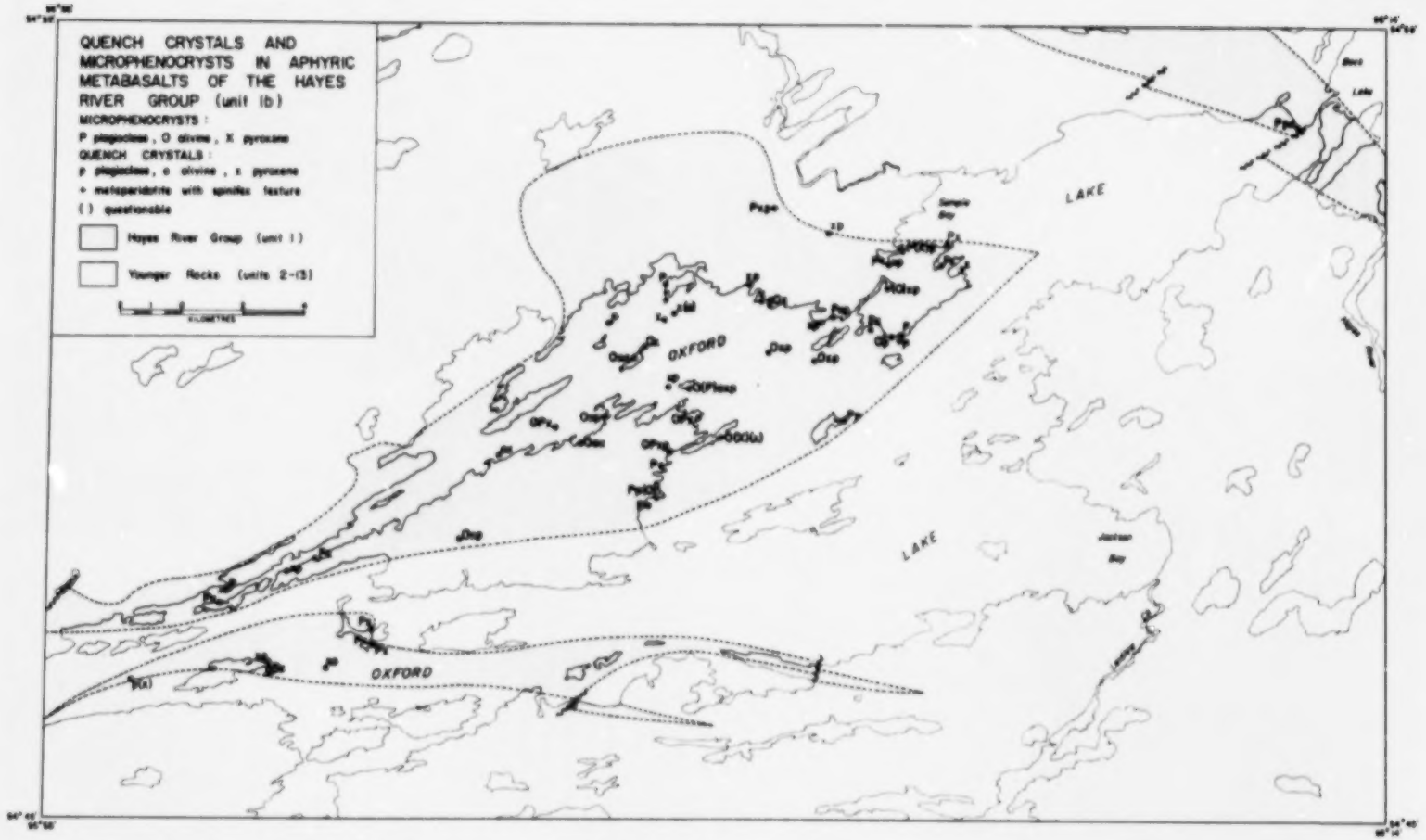

QUENCH CRYSTALS AND MICROPHENOCRYSTS IN APHYRIC METABASALTS OF THE HAYES RIVER GROUP (unit 1b)
MICROPHENOCRYSTS :
P plagioclase , O olivine , X pyroxene
QUENCH CRYSTALS :
p plagioclase , o olivine , x pyroxene
+ metaperidotite with spinifex texture
( ) questionable
Hayes River Group (unit 1)
Younger Rocks (units 2-13)
KILOMETRES
OXFORD
LAKE
OXFORD
LAKE

Figure 14: Distribution of quench crystals and microphenocrysts in basalts (unit 1) of the Hayes River Group in the Oxford Lake area.

A rather abrupt transition from plagioclase tholeiites without quench olivine, to overlying olivine tholeiites with quench olivine occurs northeast of Carghill Island (Figs. 3 and 14). This transition appears to reflect a change in composition which coincides with a lithologic break in the Hayes River Group. Porphyritic basalts (1c) and subvolcanic sills (units 1d and 1e) were documented below the lithological break, and pillowed basalts (1b) above it. The lithological break is also marked by quartz-eye rhyolite (2a1), that presumably represents the upper level of a volcanic cycle and the only ultramafic sill recorded in this part of the Hayes River Group.

Olivine tholeiites that constitute the lower level of the next volcanic cycle change in composition upwards in that plagioclase becomes the quenched phase instead of olivine. Subsequently, plagioclase instead of olivine was found as microphenocrysts, whereas plagioclase remains the quenched phase. A similar change is noticed in the much thinner north-facing monocline near High Rock Island, where olivine tholeiites are overlain by plagioclase tholeiites. The olivine tholeiites of High Rock Island overlie a metaperidotite layer with spinifex texture. However, the two rock types may not be related, as the tholeiites also change compositionally in a lateral direction at the peninsula south of Semple Bay (Fig. 14). This compositionally different magma may have been produced from another volcanic centre further east.

Miyashiro et al. (1970) showed that recent abyssal olivine tholeiites and plagioclase tholeiites plot in different compositional fields in a plagioclase (ab + an) - pyroxene (di + hy) - olivine (fo + fa) - ternary diagram, separated by a cotectic curve. The plagioclase tholeiites contain generally more Al_2O_3 than the olivine tholeiites. This relationship was also noticed in Hayes River Group basalts at Oxford Lake where the plagioclase tholeiites and olivine tholeiites are separated by an Al_2O_3/SiO_2 ratio of approximately 0.290. Melting experiments on recent abyssal tholeiites by Kushiro and Thompson (1972) suggest that olivine tholeiites can be derived from more mafic magma or mantle peridotite at depths shallower than 25 km (less than 8 kb) under anhydrous conditions. The plagioclase tholeiites cannot be derived under similar conditions from the same source, since olivine is not on the liquidus at any pressure under anhydrous conditions. Kushiro and Thompson (1972), however, point out that small amounts of water reduce the crystallization temperature of the liquidus phases and that olivine, plagioclase and clinopyroxene crystallize simultaneously at about 5-6 kb. The authors suggest, therefore, that plagioclase tholeiites may also be derived from more mafic magma or mantle peridotite, provided a small amount of water is present. Thus, an elevation of the PH_2O and possibly also a decrease in depth of the fractionation site were required either to derive the plagioclase tholeiites of eastern Carghill Channel by fractional crystallization from the olivine tholeiites, or to derive both the plagioclase and olivine tholeiites from a common more mafic source.

The modern Atlantic ocean floor olivine tholeiites and plagioclase tholeiites investigated by Miyashiro et al. (1970) and Kushiro and Thompson (1972) are olivine normative. Most Hayes River Group basalts analyzed from the Oxford Lake-Knee Lake area are quartz normative (Hubregtse, 1976). Nevertheless, Hayes River Group basalts and ocean floor tholeiites have similar microphenocryst mineralogies. Changes in chemical composition of ocean floor tholeiites by submarine weathering include a decrease of SiO_2 content, an increase in Fe_2O_3/FeO ratio and a decrease of normative olivine content, and eventually the appearance of quartz in the norm (Miyashiro et al., 1969). However, the mode of SiO_2 distribution of Hayes River Group mafic volcanics, including the olivine tholeiites and plagioclase tholeiites, is 49.75 wt.% (Hubregtse, 1976), which falls in the range of 49.59 - 50.91 wt.% reported for olivine normative ocean floor tholeiites (Miyashiro, et al., 1969). An overall decrease in SiO_2 content of Hayes River Group tholeiites by similar submarine weathering is therefore not apparent and their quartz normative composition cannot be attributed to such weathering. The chemical contrast between Hayes River Group tholeiites and modern tholeiites may indeed be genuine and the conclusion drawn from Kushiro and Thompson's (1972) melting experiments may not be applicable to the Archean tholeiites.

Flow breccia and pillow breccia (1b5)

Brecciated basalt flows (non-tectonic) were encountered in northeastern Carghill Channel northeast of Kanawastiwiwin Island. Breccias containing pillow fragments and which are intercalated with undisturbed pillow basalts, were mapped as pillow breccias (unit 1b5, Fig. 3).

Angular and vesicular fragments were documented (Fig. 15) and are interpreted as evidence for an explosive origin, rather than brecciation related to transportation as a lava flow moved downslope or was pushed ahead by new outpouring material.

Basalt flow breccias without pillow fragments (unit 1b5; Fig. 3) may have formed through fragmentation of a cooling flow top during advancement.

Porphyritic andesite and basalt, minor dacite and related sills (1c)

Massive porphyritic andesite and basalt, minor dacite (1c1)

Pillowed porphyritic andesite and basalt (1c2)

Porphyritic pillow breccia, volcanic fragmental rocks (1c3)

Except in relatively little deformed rocks most primary features of the porphyritic andesites were obliterated during upper greenschist facies grade metamorphism and intense deformation.

Lath-shaped plagioclase phenocrysts range from 0.1 to 2 cm. Less conspicuous are amphibole pseudomorphs after pyroxene or hornblende phenocrysts, which may be as large as 1 cm. Weathering of vesicles resulted in a "pockmarked" surface. Abundant plagioclase and metamorphic biotite indicate andesitic rather than basaltic compositions. The andesites are commonly enriched with carbonate.

In thin section the plagioclase phenocrysts (An = 30%) form sporadic clusters and are partially replaced by masses of epidote, amphibole and carbonate. Aggregates of recrystallized blue-green amphibolole ($\gamma \wedge c$ = 14° - 16°, δ = 0.014 - 0.016), brown biotite and opaque minerals are pseudomorphic after hornblende or pyroxene. The matrix is made up of aphanitic amphibole, epidote, plagioclase, sphene with minute ilmenite cores, quartz, opaques and carbonate. Stretched-out ovoids, up to 6 mm in length, containing mosaics of quartz, epidote or carbonate, are interpreted as recrystallized vesicles.

Megaphyric andesite, basalt and related minor intrusions (1d)

Massive megaphyric andesite and basalt (1d1)

Pillowed megaphyric andesite and basalt (1d2)

Mafic subvolcanic rocks (1e)

Equigranular gabbro (1e1)

Porphyritic gabbro (1e2)

Plagiophyric dolerite (1e3)

Mesocratic porphyry, quartz gabbro and granophyre (1e4)

The mainly hypabyssal rocks of unit 1e are easily distinguished from the basalts and pyroclastic rocks which they intruded. In the field the equigranular members of unit 1e are rather featureless, fine- to medium-grained, massive grey, greyish green and greyish black rocks. Weathered surfaces display a typical salt and pepper texture in brown, green and grey tinges. These rock types were previously

Figure 15:
Pillow breccia (unit 1b5), northeast of Kanawastiwiwin Island.

mapped as gabbro and diorite (Barry, 1960). Under the microscope, however, it appears that gabbroic textures are rare. Most samples have hypabyssal textures that are still visible despite almost complete replacement of the primary mineralogy due to upper greenschist to lower amphibolite facies metamorphism. Textural gradations between the sub-units 1e1, 1e3 and 1e4 are common. The rocks of this unit are transformed into amphibolite (unit 1h) in zones of strong deformation, particularly near the northern shore and the west end of Carghill Channel.

Composite gabbroic sills underlie much of the area around Peridotite Island in Wakahoo Lake. The sill rocks display gabbroic and porphyritic textures (units 1e1 and 1e2). An intrusive contact between chilled gabbro and peridotite (1a) is exposed on two small islands south of eastern Peridotite Island.

Hypabyssal textures are evident in thin section where both plagioclase and amphibole form porphyritic phases. Large plagioclase phenocrysts (up to 4 cm) in an ophitic groundmass characterize plagiophyric dolerite (1e3; Fig. 16).

A variety of mesocratic porphyries (1e4) with hypabyssal textures, including plagioclase and quartz-plagioclase porphyries, make up most of unit 1e. Tabular amphibole may occur as pseudomorphs after an undetermined, mafic, porphyritic mineral. Granophyric quartz-plagioclase intergrowth textures frequently dominate the groundmass of the porphyries. The porphyries and the gabbros have similar mineralogical compositions.

The plagioclase porphyries contain saussuritized plagioclase phenocrysts, with present compositions ranging from albite to andesine. The unusually clouded ophitic groundmass may contain clear saussurite-free albite. Bluish green amphibole pseudomorphs after pyroxene or hornblende may exhibit optical properties of the arfvedsonite series. Ilmenite, magnetite and other opaque minerals are accessory phases. Idiomorphic lath-shaped albite phenocrysts up to 12 mm long are surrounded by radiating micrographic textures. Hypidiomorphic, sporadically double terminated quartz phenocrysts, up to 3 mm long, are surrounded by micrographic textures and exhibit a conspicuous blue opalescent colour in hand specimen.

Plagiophyric dolerite (1e3) is associated with megaphyric andesite (1d). The contrast in grain size between the phenocrysts and the matrix plagioclase is more extreme than in the porphyritic metagabbro, and plagioclase phenocrysts are larger and more densely seeded in the plagiophyric dolerite. The plagiophyric dolerites may grade into anorthosite-like rocks, with plagioclase amounting to 90% of the rock volume (Fig. 17).

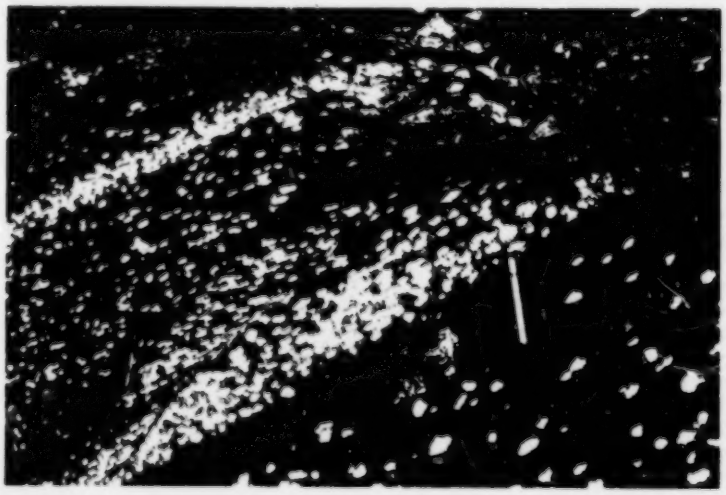


Figure 16:
Igneous layering in plagiophyric dolerite (unit 1e3) northeast of Kawapasik Narrows.

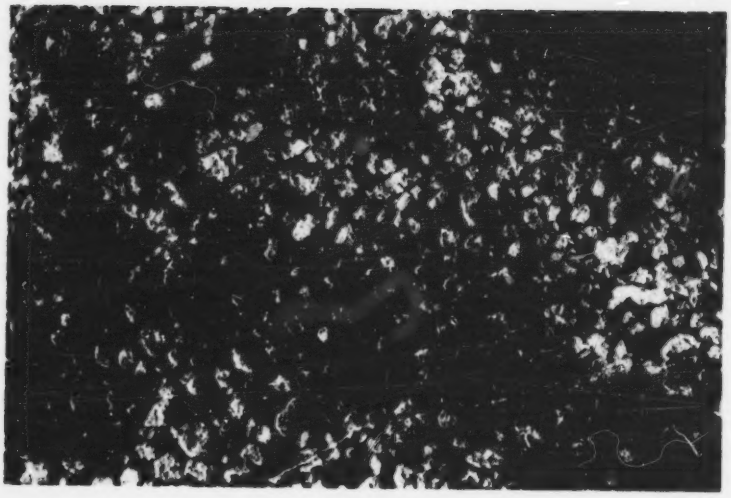


Figure 17:
Anorthositic plagiophyric dolerite (unit 1e3) west of Wapaskosowakow Lake.

The plagioclase phenocrysts contain up to 89% anorthite and exhibit weak polysynthetic albite twinning. The bytownite is partially replaced along an anastomosing network of sodic plagioclase. Other replacement minerals are epidote, chlorite and amphibolite. Secondary muscovite growth is largely lattice-controlled. Opaque inclusions are found to have clinozoisite reaction rims with the bytownite host. The interstitial matrix has an ophitic texture. Randomly oriented plagioclase laths, up to 0.8 mm, and some quartz phenocrysts are enclosed in metamorphic bluish-green amphibole ($\gamma/\wedge c = 16°$, $\delta = 0.015$) exhibiting a poikilitic texture. A clear first generation of epidote is marked by irregular rims of clouded second-generation epidote. Minute sphene grains have ilmenite cores.

The preservation of clean, non-saussuritized calcic bytownite is unusual. Apparently, this occurrence of plagiophyric dolerite was only weakly affected by the low-grade metamorphism that normally results in saussuritization of calcic plagioclase.

Two outcrops of plagiophyric dolerite and one occurrence of megaphyric andesite near Peridotite Island (Wakahoo Lake), opposite the southwestern end of the island, displays a conspicuous igneous layering over a width of 3 m. The lowest layer contains densely seeded plagioclase crystals as large as 3 cm. Next is a zone of sparsely seeded plagioclase phenocrysts, up to 1 cm in diameter, followed by a zone of amphibole "enrichment". Farther towards the top a zone occurs containing amphibole phenocrysts and ragged clusters of amphibole which may have resulted from intercumulus growth of mafic minerals. The uppermost layer in this outcrop is a gabbroic rock with small plagioclase and amphibole phenocrysts. The megaphyric rocks at the west end of Peridotite Island have a quenched basaltic matrix.

Another occurrence of plagiophyric dolerite is located at the northern shore of Carghill Channel, due north of Kanawastiwiwin Island. The stratigraphy is shown in Column A-B (Fig. 3) at the 5000 m level. The plagiophyric dolerite is overlain by an 80 m thick breccia zone, which in turn is overlain by a 75 m thick layer of locally plagiophyric dolerite, followed by another 85 m thick breccia layer. Finally, a massive porphyritic basalt (unit 1c1) overlies the upper breccia layer. The fragments of the breccias may measure up to 1 m and consist of plagiophyric dolerite and massive basalt. The larger blocks are internally fractured into smaller fragments, that still outline the shape of the blocks as they fit together suggesting an explosive origin for the breccias. It can be inferred from this stratigraphic succession that the intrusion and extrusion of megaphyric andesites was locally accompanied by phreatic explosion resulting in the formation of the volcanic breccias.

An interesting aspect of the pillowed megaphyric andesite is the random distribution of plagioclase phenocrysts throughout the pillows including the selvages. Pillowed megaphyric basalts at Cinder Lake (Green, 1975; Elbers, in prep.) contain clusters of plagioclase phenocrysts in the pillow centres. At Oxford Lake, however, abundant small angular plagioclase fragments accumulated in inter-pillow deposits and along selvages as a result of shattering of the phenocrysts during fast cooling. Plagioclase phenocrysts, up to 2 cm, were also found in pillow selvages (Fig. 18). These crystals must have survived the rapid drop in temperature. The only other explanation, post-depositional plagioclase blastesis, is not supported by microscopic examination.

In thin section, the plagioclase phenocrysts appear to be completely saussuritized, causing a yellow-green colour. The phenocrysts are enclosed in an aphanitic mass exhibiting pseudomorphosed quench plagioclase and pyroxene (see unit 1b), which forms a conspicuous contrast to the ophitic texture in the plagiophyric dolerite. The phenocrysts have minute cavities, filled with quenched liquid (Fig. 19), and are partially corroded, indicating an unstable relationship with the liquid rather than crystal growth during suspension in the magma. This precludes plagioclase blastesis after solidification of the rock.

Mafic to intermediate pyroclastic rocks, minor greywacke, argillite and basalt (1f)

This unit of fragmental volcanic rocks was mapped along Carghill Channel, where it is engulfed in the subvolcanic sills of unit 1e. Petrogenetically, unit 1f is thought to be related to the porphyritic basalt (2c) as many fragments of the pyroclastic deposits are compositionally similar to the porphyritic basalt. Moreover, in some outcrops both units are interbedded.

The composition of the fragmental rocks ranges from mafic to intermediate, and locally, felsic (unit 2b).

The size of the angular to sub-rounded fragments average 5 cm and rarely exceed 25 cm. The pyroclastic deposits can be classified as tuffs and lapilli-tuffs with the occasional lapillistone and tuff-breccia (Fisher, 1966). Interbeds of mafic greywacke and argillite suggest a mixed pyroclastic-epiclastic origin. A partially epiclastic origin is supported by results from thin section examinations.

Microscopic examination shows that the matrix is made up of brown biotite, chlorite, epidote, quartz, plagioclase, ilmenite with rims of sphene, calcite and opaques, recrystallized into an equigranular granoblastic fabric. Coloured amphibole may be present, depending on the metamorphic grade. Both the matrix and the porphyritic frag-

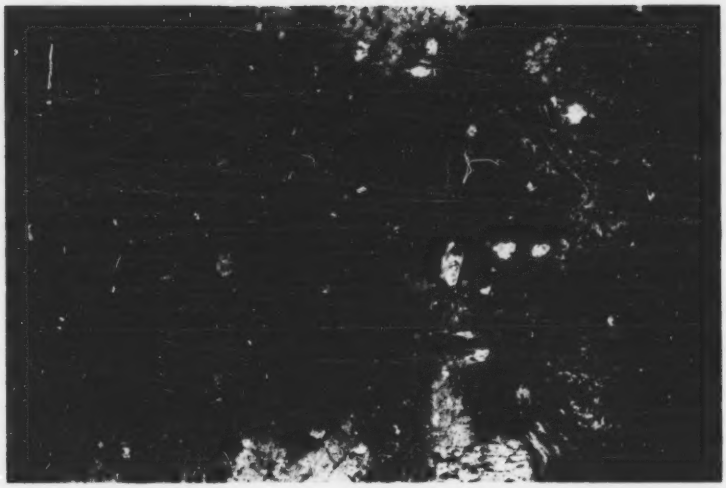


Figure 18:
Plagioclase phenocrysts in porphyritic pillow basalt (unit 1d2). Note plagioclase phenocrysts and fragments in selvages and between pillows.

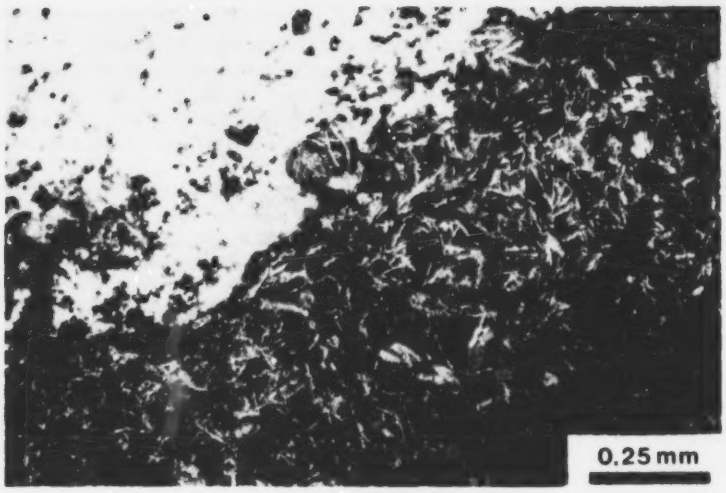


Figure 19:
Corroded rim of plagioclase phenocryst in quenched porphyritic pillow basalt (unit 1d2). Note quenched liquid in cavities.

ments contain albite phenocrysts and fragments of phenocrysts up to 1 mm. Sub-microscopic to fine grained fragments vary in composition from porphyritic basalt to rare quartz-eye rhyolite (unit 1a1). Coarser rhyolite fragments contain characteristic greyish-blue quartz-eyes. The influx of foreign material is reflected by the presence of small rounded fragments consisting of dusty epidote aggregates with an internal fabric reminiscent of the massive basalts (1b).

Epidote amphibolite, epidotized basalt (1g)
Amphibolite, amphibolitic schist (1h)
Amphibole-biotite gneiss, diopside-amphibole gneiss (1i)
Garnet amphibolite (1j)

These units comprise amphibolitic rocks of unknown origin.

The metamorphic grade and zonation of the amphibolites are discussed under Metamorphism. The amphibolites occur north of Oxford Lake, near Kwaykwaychi Bay, near Cat Eye Bay, south of High Rock Island and along the Hayes River between Knee Lake and Back Lake, and along the Carrot River. Some amphibolite facies iron formations that were documented along the southern shore of Oxford Lake, are described under unit 2c.

The amphibolites are darker and display a higher lustre than their greenschist facies counterparts. They are well foliated, fine- to medium-grained and may have a streaky appearance.

Relict porphyritic and ophitic textures are preserved sporadically in the amphibolites. Blue-green amphibole ($\gamma \wedge c = 13° - 17°$; $\delta = 0.023 - 0.027$), brown biotite, epidote, quartz, sodic plagioclase and some chlorite form syntectonically recrystallized granoblastic mosaics. Accessories are magnetite, carbonate, muscovite, apatite, and sphene with ilmenite cores. Important late-tectonic growth features are blue-green hornblende porphyroblasts, some of which are sieve-textured and riddled with pleochroic halos, and rare xenomorphic garnet porphyroblasts.

The carbonate content of some of the amphibolites may be as high as 40 vol.%. Carbonate occurs either as veinlets with minor quartz and opaque minerals, or as disseminated grains. Sporadic meionite-rich scapolite formed by reaction of plagioclase and carbonate. Sieve-textured diopside porphyroblasts may occur in the carbonate veinlets. The grain size of hornblende in the host rock increases towards the carbonate vein, reflecting a high growth rate/nucleation ratio in the volatile-rich environment. The presence of carbonate-rich amphibolites indicates that high carbonate contents are not restricted to low-grade basalts, and that the amphibolite facies metamorphism did not

have a "drying" effect by forcing carbon dioxide out of the system.

Diopside-amphibole gneisses exhibit a granoblastic mosaic of diopside and plagioclase, partially replaced by an epidote-amphibole-chlorite-carbonate association. These gneisses are calc-silicate rocks, which may represent zones of calcium enrichment in pillowed lavas. Similar rocks with primary pillow structures were documented in the Max Lake belt (Hubregtse, 1974).

Blastomylonite (1k)

Amphibolitic and semi-pelitic blastomylonites were mapped on a small lake 3 km north-northeast of Carrot Point, and about 2 km east of this location. Their compositions suggest a supracrustal origin. The blastomylonites represent the northern margin of the Hayes River Group. The northern and western sectors of the same lake are underlain by tonalitic gneisses (unit 6), which are also locally transformed into blastomylonites, particularly close to the contact with the supracrustal rocks.

The supracrustal blastomylonites contain anhedral, partially replaced garnets, which predate the mylonitization. The recrystallized groundmass is composed of plagioclase (An_{26}), quartz, muscovite, biotite or chlorite. Apatite, tourmaline and opaques are accessory minerals.

The tonalitic blastomylonites with a well developed "platten-quartz" fabric are made up of recrystallized plagioclase, biotite, muscovite, epidote and some potassium feldspar. Sphene and opaques are accessories. Relicts of plagioclase phenocrysts are still visible.

The presence of the blastomylonites indicates that the junction between the Hayes River Group and the tonalites of the Bayly Lake Complex is a fault contact. The presence of pre-tectonic garnet in the mylonites indicates an increase in the grade of metamorphism towards the northern margin of the belt in this area, similar to the increase documented in northern Carghill Channel (see Metamorphism). The tonalitic gneiss does not exhibit a noticeable change in metamorphic grade toward the blastomylonite zone, although a small intrusive body of locally blastomylonitic clinopyroxene-bearing quartz diorite occurs in the supracrustal blastomylonites. This quartz diorite contains blue-green pleochroic amphibole with occasional cores of light green clinopyroxene ($\gamma \wedge c = 18°$, $\delta = 0.027$ and $\gamma \wedge c = 43°$, $\delta = 0.022$, respectively). The igneous texture is still discernable but the "platten-quartz" fabric is also weakly developed. The clinopyroxene relicts suggest that, prior to the event of blastomylonitization, the supracrustal rocks and quartz diorite, and possibly also the tonalites, were part of the most intensely metamorphosed section in this area.

A similar zone of blastomylonite was formed at the contact of the Hayes River Group and the Bayly complex along the southern margin of the greenstone belt at Cat Eye Bay, suggesting major movements along the interface of the lithologically different groups. The fault movements took place during the older orogenic phase that predated the deposition of the Oxford Lake Group (see below).

UNIT 2: METAMORPHOSED FELSIC VOLCANIC ROCKS, SUBVOLCANIC AND RELATED SEDIMENTARY ROCKS

Distribution

Felsic rocks make up less than 1 per cent of the Hayes River Group in the Oxford Lake area. They occur along Carghill Channel and at the eastern tip of the peninsula south of Semple Bay. Remnants of an original probably continuous unit of felsic to intermediate pyroclastic rocks (unit 2b) can be traced over 14 km in the lower stratigraphic levels of the Hayes River Group.

A 10 m wide rhyolite sill (unit 2a2) was mapped along the northern shore of Carghill Island and smaller rhyolite dykes occur at the west end of Carghill Island in basalt flows (unit 1b).

The best exposure of Hayes River Group rhyolite occurs at Oxford Lake northeast of Bleak Island and consists of two, approximately 70 m thick, layers of rhyolite intercalated with massive and pillowed basalt and felsic pyroclastic rocks.

The largest occurrence of felsic volcanic rocks in the Oxford Lake-Carrot River area is an 800 m wide sequence of porphyritic rhyolite and dacite (unit 2a) and pyroclastic rocks (units 2a3 and 2b) at Wakahoo Lake. Along the Carrot River rocks of unit 2 occur at 96°08', 96°20' and 96°36'W.

The amphibolite facies felsic rocks (unit 2e, f and g) of the Cat Eye Bay area contain anthophyllite, cordierite, cummingtonite, garnet, anorthite and fuchsite, reflecting unusual whole rock compositions. The rocks are interpreted as metamorphosed iron formations, hydrothermally altered basalts, calc-silicate rocks and cherts, which evolved during a late stage of felsic volcanism.

Felsic to intermediate flows, related intrusions and volcanic fragmental rocks; minor mafic flows and sedimentary rocks (2a)

Porphyritic rhyolite and dacite, minor related intrusions, pyroclastic rocks and minor mafic flows (2a1)

Aphyric felsite (2a2)

Dacitic pyroclastic breccia, related arkose (2a3)

The flinty appearance, conchoidal fracture and common quartz eyes are distinctive features of the felsic rocks. The colour of fresh rocks may vary from white to grey to black, but weathered surfaces are creamy white with green, pink and brownish tinges. The rhyolites are distinctly cleaved if not strongly tectonized.

The dacitic to rhyolitic flows, pyroclastic rocks and sills of unit 2a are commonly porphyritic. Albite phenocrysts (up to 3 mm long) show polysynthetic albite twinning and are commonly clotted together, displaying synneusis, a feature characteristic for flows (Vance, 1961). Idiomorphic to xenomorphic quartz phenocrysts in rhyolites exhibit resorption features. The matrix is aphanitic to fine grained. An inverse relationship between the amount of biotite and the presence of quartz phenocrysts reflects a variation in chemical composition.

The eastern extremity of the peninsula south of Semple Bay is underlain by a succession that may be tectonically thickened (repeated) comprising three levels of dacitic pyroclastic breccia (unit 2a3), intercalated with pillowed basalt (1b). With increasing stratigraphic height the thickness of the layers is 30 m, 130 m and 170 m, respectively (Fig. 3). The breccias were locally reworked into arkosic sediments.

The dacitic pyroclastic breccias (unit 2a3) contain angular fragments (up to 30 cm) with minor matrix, and may grade into lapillistone beds. The pyroclastic breccias are locally intercalated with graded and crossbedded laminated arkosic sandstone beds which contain rounded dacite pebbles, and are entirely derived from the pyroclastic deposits.

Under the microscope, the arkose contains fine grained rounded fragments of plagioclase phenocrysts. The overall grain size of the arkose is smaller than the grain size of the dacitic source. The aphanitic matrix is mainly made up of quartz and plagioclase, but contains accumulations of biotite, chlorite and opaque minerals. The sediments are locally enriched in blue-green tourmaline and post-tectonic, bottle green chlorite porphyroblasts.

Well foliated biotite-bearing porphyritic dacites (2a1) were mapped at the southern shore of Stubbs Lake. It is not clear whether they formed as flows or sills. The dacites are associated with garnet amphibolite. Tectonically interleaved hybrid rocks, derived from the dacites and the amphibolites, resemble the hybrid rocks mapped along the southern shore of Oxford Lake and the Carrot River.

Felsic to intermediate volcanic fragmental rocks, minor rhyolite and sedimentary rocks (2b)

The pyroclastic rocks of this unit are distinguished from the pyroclastic rocks of unit 2a3 because of their different composition and their intimate association with the mafic to intermediate pyroclastic rocks (unit 1f) and the porphyritic basalts (1c). The felsic pyroclastic rocks of unit 2a3 occur with aphyric metabasalts (1b).

The angular creamy weathered fragments of the tuff-breccias and lapilli-tuffs may measure up to 75 cm, but are generally smaller than 40 cm, and consist of porphyritic dacite and rhyolite. Conspicuous plagioclase phenocrysts and oval quartz phenocrysts measure up to 3 mm. The fragment/matrix ratio may vary widely, and the pyroclastics may grade into coarse- to fine-grained crystal tuffs, containing plagioclase phenocrysts as large as 7 mm.

Original tabular, angular albite (An_{0-8}) phenocryst fragments exhibit polysynthetic albite twinning. The commonly recrystallized matrix is made up of plagioclase, muscovite, quartz, chlorite, epidote, carbonate, sphene, apatite and leucoxene, and sporadic epiclastic, rounded epidote fragments and aggregates, probably derived from basalt.

Iron formation (2c)

Iron formations are sporadic in the Hayes River Group. They were mapped at the west end of Carghill Island, on the High Rock Island, in Cat Eye Bay, at the west end of the Carrot River greenstone belt and on Peridotite Island.

Approximately 25 cm thick magnetite iron formation bands were mapped at the west end of the Carrot River greenstone belt intercalated with porphyritic metabasalts. They are made up of alternating "ribbons" consisting of almost pure quartz and magnetite.

A 1-2 metre thick, banded layer of magnetite iron formation can be traced along strike over 2 km near High Rock Island (Fig. 20). Magnetite, up to 0.8 mm, is partially replaced by red-brown to green-brown biotite along fractures. Pale green amphibole ($\gamma \wedge c = 13°$, $\delta = 0.020$) occurs in aggregates. Quartz forms polygonal to seriate mosaics and occurs particularly in stress shadows of magnetite. A post-tectonic assemblage of orange-brown biotite, amphibole and bottle-green chlorite has randomly overgrown the older mineral association, giving the rock a hornfelsic appearance.

The contact-metamorphic texture was caused by the peridotite sill (unit 1a) which engulfed and partially assimilated the iron formation. A similar association of peridotite and iron formation exists on Peridotite Island. There, the iron formation is a delicately banded cummingtonite quartzite (silicate facies iron formation).

Fuchsite quartzite (2e)
Anthophyllite-, cordierite- and cummingtonite-bearing gneisses (2f)
Calc-silicate gneiss (2g)

The rocks of these units have commonly undergone amphibolite facies metamorphism. They occur in the Cat Eye Bay area, where the geological history is complicated by several intrusive and diastrophic events. Amphibolitized pillowed basalts (unit 1b) form the island chain which encloses Cat Eye Bay. Towards the south the basalts grade into amphibolites (unit 1h) due to an increase in metamorphism.

These metabasalts were intruded by pre-tectonic porphyries that are probably related to the southern tonalite complex. The feldspar porphyries and the basalts were hybridized during intrusion, yielding rocks of intermediate composition. Based on their composition these rocks have been interpreted mistakingly as metasediments (Campbell et al., 1972). The hybridization process was followed by deformation accompanied by amphibolite facies metamorphism, leading to an obliteration of original field relations and the formation of several west-northwest trending mylonite zones in southwestern and northwestern Cat Eye Bay.

The contact between the volcanic rocks (units 1 and 2) and the tonalites (units 4 and 6) is a zone of heavily sheared, interlayered amphibolites and tonalites.

The mylonites and amphibolite facies rocks are truncated by a late-tectonic granodiorite-tonalite (unit 7) in central Cat Eye Bay. A late phase of deformation is responsible for the gneissoid structure of the granodiorite and the parasitic S and Z folds of the other mylonites and gneisses.

Rusty weathering rocks at the southwestern shore of Cat Eye Bay containing sub-calcic and orthorhombic amphiboles, quartz, magnetite and pyrite, are interpreted as amphibolite grade iron formations. The colour of the fresh rock surface varies from creamy brownish white to greenish black, depending on the quartz/mafic mineral

Figure 20:
Magnetite iron formation (unit 2c), east of High Rock Island. Note the ribbed surface caused by weathering of the mafic layers and the white marly deposits of uncertain age.

ratio. The streaky appearance is caused by mylonitization. Cummingtonite ($\gamma\Lambda c = 21°$, $\delta = 0.028$), blue-green amphibole ($\gamma\Lambda c = 16°$, $\delta = 0.025$) and minor anthophyllite form polygonal mosaics with quartz and magnetite. Pyrite may be present instead of magnetite. Cummingtonite is locally partially replaced by pyrite, which in turn may be partially replaced by a goethite-like mineral or limonite.

Fuchsite quartzite (2e) is associated with amphibolite grade iron formation and hybrid rocks, that are mixtures of Hayes River Group basalt and feldspar porphyries of the Bayly Lake Complex. Fuchsite quartzite was mapped at the southern shore of Cat Eye Bay, on small islands in western Cat Eye Bay and 1.5 km south of Kawapasik Narrows.

Fuchsite quartzite occurs as bright apple-green lustrous, schistose rocks in layers varying in width from 1 cm to 1 m. The bright green colour changes often to grey or grey-green from the centres of the layers towards the margins (Fig. 21), reflecting a compositional change of the mica from fuchsite to muscovite and/or biotite. The aphanitic to fine grained quartzites comprise stringy aggregates of faint blue to bluish green pleochroic fuchsite, alternated with post-tectonically recrystallized quartz mosaics. Fuchsite may make up 40 per cent of the rock. The fuchsite aggregates contain apatite, rutile and magnetite which is occasionally replaced by hematite.

The close association of fuchsite, quartzite and metamorphic iron formation may suggest that the quartzites are metamorphic derivatives of iron formations or possibly chert deposits.

Calc-silicate gneisses (2g), east of Cat Eye Bay at 95°32'W -54°47'45"W, contain abundant garnet, anorthite (An_{93}), clinozoisite, actinolite, quartz and white mica, and minor amounts of biotite, cummingtonite, magnetite, pyrite and tourmaline (see also Metamorphism). The garnet-anorthite gneiss occurs as layers within amphibolites (1h). They may represent calcium enriched zones of pillows or may have formed during hydrothermal alteration.

Cat Eye Bay sulphide mineralization

Cordierite-anthophyllite gneiss is associated with the amphibolite facies iron formation. The random orientation of anthophyllite suggests that the gneiss was affected by contact metamorphism. Cordierite, quartz and magnetite are major phases. Biotite, chlorite and apatite are minor constituents. Similar cordierite, anthophyllite and garnet-bearing rocks and iron formations were described at Utik Lake (Weber, 1974), where these rocks were interpreted as metamorphosed altered basalts. Elsewhere, rocks of this type are described as metamorphosed, altered wall-rocks situated adjacent to volcanogenic massive sulphide deposits (Sangster, 1972). Particularly calcium-alkali deficient, magnesium-iron enriched cordierite-anthophyllite rocks, which have limited stratigraphic extent and cross-cut existing stratigraphy, are thought to be alteration zones representing pre-existing volcanic conduits which may have served as feeders for massive sulphide deposition (Sangster, 1972).

Sphalerite, galena, chalcopyrite, silver and gold were discovered in southwestern Cat Eye Bay in the early 1920s (see Southard, 1977). Haskins and Evans (1976) report that the sulphides are contained within a silicified zone, consisting of highly folded and broken quartz "veins" within and parallel to the mylonite zone that underlies the southwestern shore. The highest Zn-value, 2.5%, was found in a 1.76 m section of a 59 m long drill core. Replacement of cummingtonite by pyrite suggests that the sulphides were introduced or remobilized during or after the amphibolite facies metamorphism. It seems likely that the sulphides at Cat Eye Bay were deposited during late-stage felsic volcanism and redistributed during subsequent metamorphism.

UNIT 3: METAMORPHOSED VOLCANOGENIC SEDIMENTARY ROCKS AND MINOR VOLCANIC ROCKS

Greywacke, tuff, minor intermediate and mafic flows and volcanic fragmental rocks (3a)
Monomictic conglomerate (3c)
Polymictic conglomerate (3d)

Sediments constitute a minor part of the Hayes River Group in the Oxford Lake and Carrot River area. Some greywacke was mapped in Carghill Channel. Conglomerates have only been documented on Bleak Island and southeast of Kawasichewasik Rapids.

Greywacke beds (3a), up to 15 m thick, are intercalated with porphyritic basalts (1c) and mafic to intermediate pyroclastic deposits of unit 1f. The fine- to medium-grained schistose and mica-rich greywackes have been derived from Hayes River Group volcanic rocks. Under the microscope, fine- and medium-grained, rounded and subrounded fragments of porphyritic basalt, porphyritic rhyolite and plagioclase phenocrysts are easily detectable. The matrix consists of chlorite, biotite, carbonate, sericite, sphene, quartz, opaque minerals and detrital plagioclase.

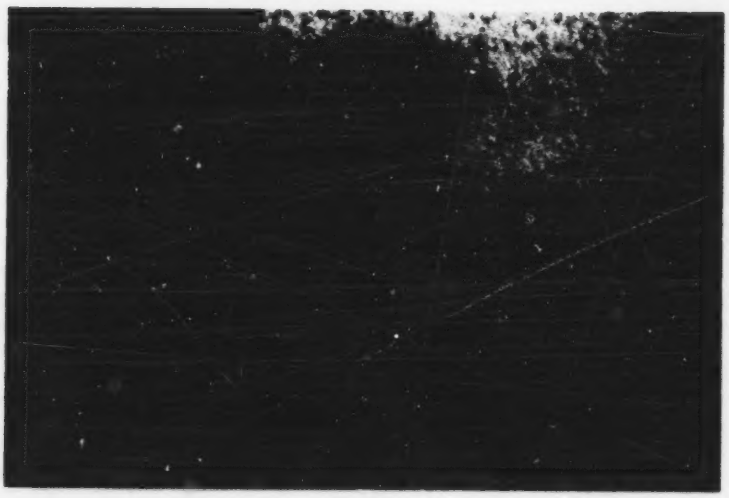


Figure 21:
Fuchsite quartzite xenoliths (unit 2e) in feldspar porphyry (unit 4f) in Cat Eye Bay. Note change in colour towards the margins of the fuchsite quartzite layers caused by a compositional change of the mica from fuchsite in the centre to muscovite- and biotite-like micas at the margins.

Arkosic sediments, intercalated with dacitic pyroclastic breccias (unit 2a3) 1.5 km south of Semple Bay, were described under unit 2a.

An intraformational monomictic conglomerate (3c) southeast of Kawasichewasik Rapids contains approximately 1 m thick cobble beds. The cobbles are rounded and consist of medium grained, equigranular gabbro (unit 1e). They range between 2.5 and 7.5 cm in size and make up 60 volume per cent of the rock.

Volcanogenic polymictic conglomerate (3d) at Bleak Island disconformably overlies a sequence of pillowed metabasalt (1b2) and variolitic pillowed metabasalt (1b3), which is overlain by an intravolcanic sill (unit 1e1 and 1e4) with an eroded top. The conglomerate directly overlying the gabbroic sill contains sub-rounded gabbroic cobbles and boulders, up to 70 cm in size, surrounded by a matrix of similar composition. The size of the fragments decreases and their composition changes stratigraphically upwards. Near the top the conglomerate consists of rounded pebbles and cobbles of green speckled variolitic pillowed basalt, brown non-variolitic basalt, light greyish green gabbro and creamy white rhyolite. The basalt fragments and gabbro are probably derived from the identical basalt flows and gabbro sill at the northern tip of Bleak Island. The nearest exposure of rhyolite which was possibly the source for the rhyolite fragments occurs 4.3 km east-northeast of the conglomerate on the mainland.

The presence of gabbroic rocks in the conglomerates of the Hayes River Group indicates that the deposition of the volcanic rocks was interrupted by periods of erosion during which volcanic flows and deeper-seated hypabyssal sills were eroded.

THE BAYLY LAKE COMPLEX (UNITS 4, 5, 6, 7)

Definition

The term Bayly Lake Complex is formally introduced to include rocks which postdate the Hayes River Group but predate the Oxford Lake Group. The Bayly Lake Complex comprises rocks of tonalitic and granodioritic composition, including pre-tectonic intrusive, volcanic and gneissic rocks (units 4, 5 and 6, respectively) and late-tectonic intrusive rocks (unit 7). Bayly Lake is located between Knee Lake and Gods Lake and is partially underlain by a granodiorite pluton of unit 7, the Bayly Bay granodiorite (Gilbert, in prep.). Intrusive relationships between the older Hayes River Group and units 4 and 7 of the Bayly Lake Complex are exposed at Bayly Lake. Detritus derived from the Bayly Bay granodiorite occurs in conglomerate of the Oxford Lake Group at Gods Lake (Gilbert, op. cit.)* Intrusive relationships of units 4 and 7 with the Hayes River Group were also documented along the southern shores of Oxford Lake and the Carrot River. The contacts between the volcanic rocks (unit 5) and the tonalite gneisses (unit 6), and the Hayes River Group, are either mylonitized or obliterated by intrusions of units 4 and 7.

Massive and gneissic tonalites of units 4 and 6 underlie the area south of the Oxford Lake-Carrot River greenstone belt. The complex extends eastwards towards Munro Lake and southern Gods Lake (Elbers, in prep.; Marten, in prep.). The area north of Oxford Lake is also underlain by members of the Bayly Lake Complex, although much of this terrain has been intruded by younger granodiorite (unit 11).

Petrography

UNIT 4: METAMORPHOSED INTRUSIVE ROCKS OF MAINLY TONALITIC COMPOSITION; MINOR GRANODIORITE AND GABBRO

Gneissic tonalite (4b)

Porphyritic tonalite, minor porphyritic granodiorite (4c)

Quartz-feldspar porphyry, feldspar porphyry (4f)

Hybrid rocks derived from units 1, 2 and 4 (4g)

A complex of foliated tonalite and minor granodiorite was mapped from the west end of the Carrot River to Michikinabish Lake (see also Gilbert, op. cit.), and in the heavily drift-covered area between Semple Lake and Carrot Bay (western Oxford Lake). The transition between units 4 and 6 is gradational as unit 4 becomes progressively more gneissic towards unit 6. Therefore, contacts shown on the map are approximate. The characteristic compositional and textural layering and the concordant amphibolite bands of unit 6 are generally lacking in unit 4.

Modal analyses are shown in the plagioclase-potassium feldspar-quartz plot (Fig. 22). The compositional range within unit 4 is limited to the tonalite field. Quartz diorites are rare. The tonalitic rocks west of Lynx Bay were hydrothermally altered.

CARROT RIVER

The Carrot River area is mainly underlain by gneissoid tonalitic rocks of units 4b, 4c and 4f. Less abundant gneissoid granite and granodiorite of unit 7c occur south of Peridotite Island, around Hargreaves Lake, and extend towards Carrot Bay. Tonalites underlie the area north of the Carrot River and the area south and southeast of the granite body (unit 7c). Relationships north of Hargreaves Lake suggest that the tonalites are older than the granite.

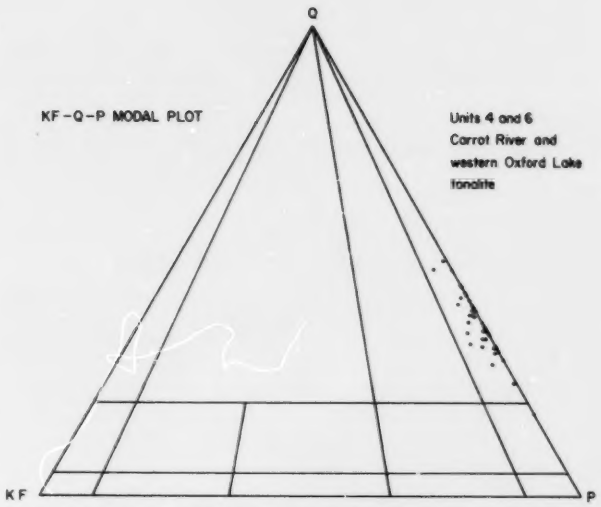


Figure 22: Potassium feldspar-quartz-plagioclase modal plot for units 4 and 6.

The tonalitic rocks comprise a variety of textural types ranging from coarse- to medium-grained equigranular tonalite (4b), to porphyritic tonalite (4d) and to fine- to medium-grained quartz-feldspar porphyry (4f). The tonalite complex is a multi-phase intrusion. Several generations of tonalite may be exposed in one outcrop.

The porphyritic tonalites and the quartz-feldspar porphyries surround the related dacitic pyroclastic deposits at Lynx Bay (unit 5). Another quartz-feldspar porphyry body occurs south of the Hayes River Group in the central part of the Carrot River. Coarse grained equigranular counterparts are restricted to the central and southern part of the tonalite complex. The areal distribution of the non-porphyritic and porphyritic coarse grained tonalites and the pyroclastic deposits suggests that these rocks represent increasingly shallower crustal levels of one tonalite pluton which breached the surface leading to the formation of the volcanic rocks.

The quartz-feldspar porphyry body and the porphyritic tonalites south of Hargreaves Lake are part of this tonalite complex, although separated from the rocks of the Hayes River Group by the younger granite (7c), which intruded after the emplacement of the tonalites near the subsurface - cover-rock contact. Younger marginal intrusions of this type were also mapped in southern Oxford Lake. Hydrothermal alteration features in the quartz-feldspar porphyry body south of Hargreaves Lake support the model for the high level emplacement of this body.

Although modal compositions of units 4b, 4c and 4f cover the tonalite field (Fig. 22), chemical compositions may include trondhjemite. Quartz, plagioclase, amphibole, epidote, chlorite and biotite are the major constituents. Amphiboles exhibit yellow-green dark blue-green pleochroism. Biotite colours range from green-brown to red-

* This geological field evidence does not agree with a recent Rb-Sr whole rock age (Cheung, 1978) derived from the Bayly granodiorite which suggests that the pluton is younger than the Oxford Lake Group. Either the conglomerate boulders were derived, not from the Bayly Bay granodiorite but from an older petrographically similar pluton, or the Rb-Sr age dates an event after the emplacement.

brown. Biotite and amphibole are partially replaced by pistacite and chlorite. Microcline may occur as interstitial grains (up to 5 vol.%). Sphene and apatite are common accessories.

The coarse- to medium-grained non-porphyritic tonalites display a greyish white weathered and fresh surface. Freshly cut surfaces of hydrothermally altered rocks are greenish grey due to chloritization of biotite and hornblende, and the saussuritization of plagioclase, particularly in porphyritic tonalite and quartz-feldspar porphyry in which blue opalescent quartz phenocrysts and greyish green plagioclase phenocrysts are surrounded by a green chloritized matrix. Propylitic alteration of this type has frequently been found around porphyry copper mineralization systems (Lowell and Guilbert, 1970). Haskins and Stephenson (1974) related the alteration features in the tonalite to disseminated chalcopyrite and molybdenite mineralization in the Cooney-Lynx Bay area. Pistacite, chlorite, carbonate and rutile are the most significant alteration products that form at the expense of biotite and amphibole. Biotite is commonly replaced by yellow-orange pleochroic pistacite, still exhibiting the "platy" biotite structure fringed by chlorite-sphene aggregates. Amphibole is pseudomorphically replaced by chlorite, carbonate, quartz and rutile.

CONTACT WITH THE HAYES RIVER GROUP

Intrusive relationships between the Hayes River Group rocks and the tonalites are exposed in a mylonitized zone along the southern shore of western Wakahoo Lake. The most prominent rock is a quartz-feldspar porphyry containing conspicuous deep blue opalescent quartz and white plagioclase phenocrysts in a greenish grey matrix. The porphyry has been transformed locally into a creamy white, aphanitic mylonite with drawn-out "quartz eyes". Disseminated pyrite is a common accessory. In thin section, the rocks appear to be hydrothermally altered. The plagioclase phenocrysts are replaced by sericite and clinozoisite. Pseudomorphs after mafic minerals are made up of clinozoisite, chlorite and sphene. Fine grained grey-green basaltic and medium grained gabbroic rocks of the Hayes River Group are intruded by the quartz-plagioclase porphyries. The mafic and felsic rocks are strongly sheared and tectonically interlayered in typically gossaned mylonite zones. Pyrite is the common sulphide, but traces of chalcopyrite were noticed.

OXFORD LAKE

The tonalites of unit 4 of the southern Oxford Lake region constitute an approximately 4 to 5 km wide zone between the Hayes River Group sequence and the tonalite gneisses of unit 6.

An intrusive relationship between unit 4 and the Hayes River Group is exposed in the Cat Eye Bay area. The contact zone is juxtaposed twice, due to repetition by two major faults (see Structure) near High Rock Island, where major units were mapped from south to north as follows:

- Gneissoid tonalites grade into porphyritic tonalite and quartz-feldspar porphyry towards the north, west of Pinapankos Narrows.
- Enclaves of black dense amphibolite with relict pillow structures occur in the tonalites south of High Rock Island and are considered part of the Hayes River Group.
- A dextral wrench fault underlies the channel south of High Rock Island.
- Porphyritic, massive tonalites (4c) that underlie the southern part of High Rock Island intrude the mafic and ultramafic rocks of the Hayes River Group of northern High Rock Island and adjacent islands.
- The third and northernmost intrusive relationship between basalts and tonalites is exposed on the smaller islands, 1 km northeast of High Rock Island, where fuchsite schists and hybrid rocks derived from basalt and feldspar porphyry, similar to occurrences in western Cat Eye Bay, were documented.

SOUTHWEST OF OXFORD LAKE

The tonalites south of Oxford Lake have a gneissoid appearance and are comparable to those of the Carrot River area.

The tonalites are made up of blue-green amphibole, brown to green biotite, plagioclase, quartz and epidote. Sphene, apatite and opaque minerals are accessory phases. Biotite and amphibole are partly replaced by chlorite and epidote. Plagioclase is sericitized in porphyritic rocks. Secondary biotite, potassium feldspar, epidote, carbonate and sericite were noticed in the gneissoid porphyritic tonalites opposite the southernmost tip of High Rock Island, and are indicative of hydrothermal alteration as documented in the Carrot River area. The gneisses contain chalcopyrite specks. Pyrite occurs widely in disseminated form and as tiny stringers. Rutile after sphene, ilmenite, or both, is conspicuously present in the tonalites over the entire shore opposite High Rock Island. Rutile is restricted to this area and is interpreted as a product of hydrothermal alteration. Sphene is commonly the titanium phase throughout the tonalite complex. Sphene rims around rutile resulted from metamorphism which postdated the alteration processes. Enclaves of Hayes River Group metabasalts underwent similar mineralization and hydrothermal alteration. Disseminated pyrite and stringers of pyrite are common. Rutile is an accessory, and also occurs in diabase dykes (unit 4h) that cut the porphyritic tonalites.

The tonalites are cut by granite sills (unit 7b) and related pegmatite and aplite dykes. The granite contains dark brown biotite, microcline, myrmekite, plagioclase, quartz and minor epidote, muscovite and green amphibole.

Calcium-rich xenoliths, including marble and calc-silicate rocks, were found in the tonalitic gneisses near Omasesokwapa Point and on the western shore of the Hayes River. The marble is a grey, fine grained foliated rock and contains carbonate, mica and magnetite. The mica varies in colour throughout the rock and may resemble biotite, phlogopite or fuchsite. The mineral content of the calc-silicate inclusions indicates that they were derived from altered supracrustal rocks.

CAT EYE BAY

Intrusive relationships between the Hayes River Group sequence and porphyries and porphyritic tonalites of unit 4 are well exposed in the western Cat Eye Bay area. The island chain enclosing the bay is underlain by pillowed basalts (1b), which are cut by dykes and sills of fine- to medium-grained plagioclase porphyry and quartz-plagioclase porphyry containing twinned and zoned plagioclase (An 20%), quartz, biotite, muscovite and minor sphene, ilmenite, epidote, apatite and opaque minerals. Contact metamorphic aureoles with garnet enrichment are developed in the basalts cut by the larger dykes.

Contacts between the porphyries and the basalt become increasingly more vague with an increase in the overall amount of porphyry in a southerly direction. Hybridization of the two contrasting rock types yielded an intermediate rock (unit 4g, Fig. 23) that is comprised of amphibole, biotite, muscovite, plagioclase, quartz, epidote, opaque minerals and local garnet. Advanced stages of hybridization are well exposed on the islands in western Cat Eye Bay, where vague green enclaves of basalts occur in a creamy white matrix of hybridized basalt and porphyry (Fig. 24).

The volcanic sequence of Cat Eye Bay also includes metamorphosed hydrothermally altered basalts, iron formation and possible chert. Sigmoidal inclusion trails in the garnets indicate continuous growth during an earlier stage of a regional metamorphism. The accompanying deformational event culminated in the formation of several west- northwest-trending mylonite zones in southwestern and northwestern Cat Eye Bay. The hybrid rocks were transformed to white-grey-green striped mylonites which subsequently were cut by dykes of the Cat Eye Bay tonalite (unit 7b; Fig. 25).

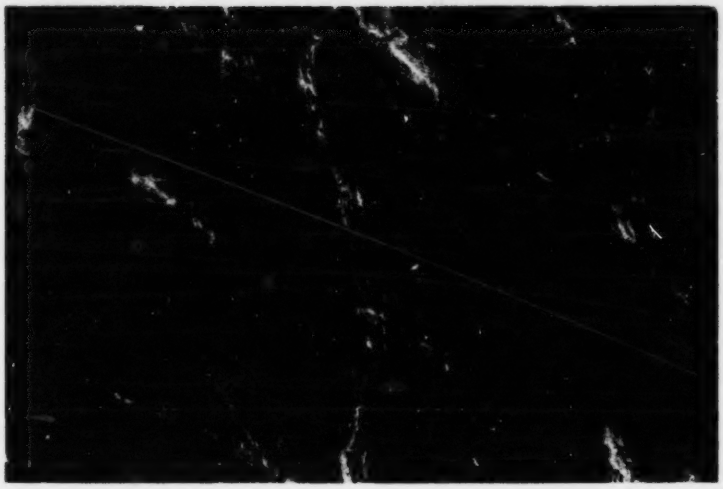


Figure 23:
Deformed partially assimilated basalt (unit 1b) in porphyry (unit 4f) forming hybrid gneisses (unit 4g); Cat Eye Bay.

Figure 24:
Weakly deformed grey patches of assimilated basalt (unit 1b) in porphyry (unit 4f) forming hybrid gneisses (unit 4g); Cat Eye Bay.

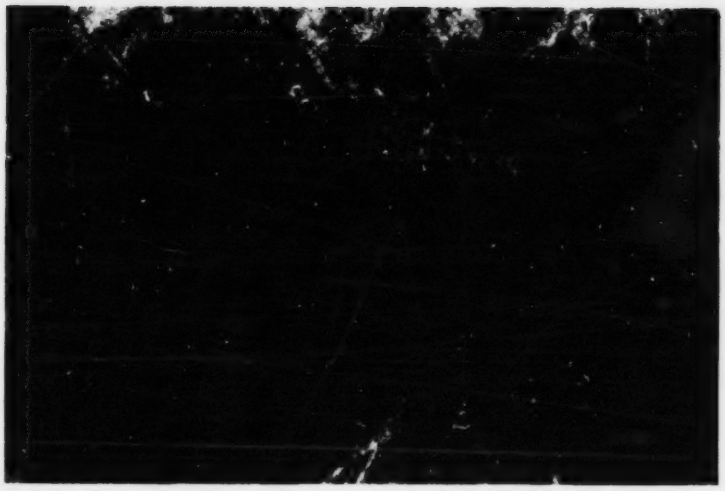


Figure 25:
Layered mylonitic hybrid gneisses (unit 4g) cut by porphyry dykes of the late-tectonic Cat Eye Bay tonalite (unit 7b).

HIGH ROCK ISLAND

The southern half of High Rock Island and some small islands to the east are underlain by locally porphyritic, massive to gneissoid, medium- to coarse-grained tonalite and quartz-plagioclase porphyry.

This body is mineralogically similar to the tonalites of the Carrot River and southern Oxford Lake areas. Disseminated pyrite, sporadic chalcopyrite and propylitic alteration features were documented. Heavily pyritized samples contain yellow-blue, anomalously birefrigent clinozoisite. The tonalite is intruded by up to 20 m wide hydrothermal quartz-carbonate-chlorite veins with sporadic sulphides (unit 5c), diabase (4h) and lamprophyre (4i). Gossans are common in the major shear zones that surround this tonalite body.

WESTERN SEMPLE RIVER

The massive and gneissic tonalites of units 4 and 6 that underlie the western Semple River area are identical to those previously described. The contact between the tonalites (4) and the tonalitic gneisses (6) is gradational. The younger Semple River granodiorite (11) and heavy drift cover obscure the relationship with the Hayes River Group.

The easterly-trending main foliation cuts across the crude lithological boundaries in the area northwest of Oxford Lake. This contrasts with southern Oxford Lake, where lithological boundaries and major structures are parallel. The cross-cutting structural trend was formed during a younger tectonic event, which postdated the Oxford Lake Group since the granodiorite (11) was also affected by it.

Diabase and Gabbro (4h)

Metamorphosed diabase and gabbro dykes (up to 100 m wide) are abundant in the tonalites of unit 4. They are texturally and mineralogically similar to the equigranular, fine- to medium-grained gabbros of unit 1e1. Chilled margins are preserved in undeformed domains.

Lamprophyre (4i)

The lamprophyres are medium- to fine-grained and black with a conspicuous lustre due to high amphibole and biotite contents. Mafic phenocrysts (up to 0.5 cm) stand out on the weathered surface. The colour indices range from 50 - 100.

Stubby columnar idiomorphic clinopyroxene phenocrysts with replacement rims of colourless to light green amphibole are well preserved in one dyke. Amphibole pseudomorphs after stubby clinopyroxene were documented in another sample. Primary hornblende has a prismatic shape and is distinguishable from pseudomorphosed clinopyroxene. Biotite and hypidiomorphic plagioclase occur as groundmass phases. The lack of potassium feldspar and the absence of biotite phenocrysts indicate that the lamprophyres are spessartites and camptonites. The camptonite dykes have a high colour index and contain no quartz or feldspar. Their groundmass is made up of greenish-brown biotite, amphibole, chlorite, carbonate, minor muscovite and apatite with purplish-brown, dusty cores. The groundmass plagioclase of the spessartite is partially replaced by clinozoisites and minor epidote. Other groundmass minerals are prismatic amphibole, greenish-brown biotite, quartz, chlorite, carbonate and apatite.

Amphibolite (4j)

This unit comprises mafic rocks of uncertain origin, which are locally abundant in the tonalites of unit 4. Amphibolite layers of varying width and extent occur profusely near the contact zone with the Hayes River Group and the tonalitic gneisses of unit 6. They may represent recrystallized mafic dykes (units 4h, 4i) and mafic xenoliths derived from the Hayes River Group. The amphibolites are petrographically similar to those described as unit 6b.

UNIT 5: LYNX BAY ASSEMBLAGE: METAMORPHOSED EXTRUSIVE ROCKS OF ANDESITIC COMPOSITION, RELATED SEDIMENTARY ROCKS; MAFIC DYKES AND CARBONATE-QUARTZ VEINS.

This unique assemblage underlies the Hyers Island-Lynx Bay region. The extrusive rocks of unit 5 are intermediate in composition and are considered to be the extrusive counterparts of the tonalitic rocks of unit 4 with which they are intimately associated. Unit 5 is lithologically different from the other units of the Bayly Lake Complex and has been designated as the Lynx Bay assemblage.

The volcanic rocks of the Lynx Bay assemblage contrast with those of the Hayes River Group (Table 2).

The area of Lynx Bay, Hyers Island, Carrot Point and Cooney Lake is cut by numerous mylonite and shear zones. The origin of the associated highly sheared and commonly carbonatized, reddish pink quartz-sericite-chlorite schists is uncertain. The rocks of the Lynx Bay

TABLE 2
Characteristics of the Hayes River Group and the Lynx Bay Assemblage

HAYES RIVER GROUP	LYNX BAY ASSEMBLAGE
mainly flows; minor pyroclastic rocks	pyroclastic rocks and porphyries
mainly basalts; minor rhyolite	andesites and dacites
generally non-porphyritic	porphyritic
mainly melanocratic	generally leucocratic
igneous counterparts unknown	intimately associated with igneous counterparts
affected by local hyrdothermal alteration and low- to medium-grade regional metamorphism	affected by pervasive carbonatization and hydrothermal alteration on a regional scale, followed by low-grade regional metamorphism
associated sediments are mainly greywackes, chert and iron formations	associated sediments are quartz wackes, conglomerates and argillites
minor disseminated sulphide mineralization; possible massive sulphide mineralization	relatively rich in disseminated, vein-controlled and possibly also massive sulphide mineralization

area have been interpreted previously as metasediments of the Oxford Lake Group (Barry, 1960; Campbell, 1971a). However, lesser deformed zones of the Lynx Bay area are underlain by andesitic and dacitic subvolcanic and pyroclastic rocks which are compositionally similar to the plagioclase and quartz-plagioclase porphyries and porphyritic tonalites in northern and southern Lynx Bay.

The Hyers Island-Lynx Bay region was prospected for more than seven decades because of several sulphide occurrences (See Barry, 1960; Haskins and Stephenson, 1974; and Southard, 1977).

Shear zones

The direction of the shear zones changes from easterly in Carrot Bay and northeastern Lynx Bay to northeasterly in southern Lynx Bay. The overall structure is a set of faults diverging out of Oxford Lake into Lynx Bay. Small-scale parasitic folds indicate right-lateral movement in the Cooney Lake-Hyers Island-Carrot Point area. However, left-lateral movements occur in southeastern Lynx Bay along two northeast-trending faults which converge to the north and separate porphyritic tonalites and pyroclastic rocks from gneissic tonalite. Fault breccias are exposed on the western shore of the southernmost arm of Lynx Bay and along the eastern margin of the peninsula directly east of the same arm. An offset of at least 5 km along this fault system is indicated by the displacement of the omnipresent porphyritic rim facies of the unit 4 tonalites in the southern Lynx Bay-High Rock Island area.

Several small islands and reefs of peridotite are aligned along the left-lateral fault zone and it appears that the peridotites were affected by the shearing. Talc schists were observed on the sheared contacts between the peridotites and tonalites. The origin of the ultramafic rocks and their relationship to the surrounding tonalites is unclear. It is postulated that they are left-laterally displaced remnants of the Hayes River Group peridotite layer that was mapped near High Rock Island.

Field evidence of an age relationship between the left-lateral and right-lateral faults is found in southeastern Lynx Bay, where east-trending shear zones and structures are truncated by the northeast-trending left-lateral faults.

Intermediate and felsic pyroclastic breccia and tuff breccia (5a)
Intermediate and felsic tuff and lapilli-tuff (5b)

Pyroclastic rocks are the most distinctive members of the Lynx Bay assemblage and are best preserved in areas of little deformation along the shores of western Lynx Bay and southern Hyers Island. Pyroclastic breccias (unit 5a1, fig. 26) containing bombs with a longest dimension of at least 20 cm are limited to southwestern Lynx Bay and southwestern Hyers Island. Less coarse, mainly dacitic pyroclastic rocks (5a2) and dacitic tuffs (5b) were mapped on Hyers Island and locally at the southwestern shore of Lynx Bay.

The pyroclastic fragments are subrounded to angular, fine grained tonalitic porphyry (Fig. 27) and plagioclase crystals up to 5 cm. The fragments are very similar to the porphyries of unit 4. They contain sericitized, carbonatized plagioclase phenocrysts and quartz phenocrysts in a matrix of sericite, chlorite, biotite, plagioclase, quartz, carbonate and opaque minerals.

The matrix of the pyroclastic rocks is a highly chloritic feldspathic tuff, containing angular albite phenocrysts that are partially carbonatized, sericitized or silicified. Matrix minerals are sericite, chlorite, biotite, plagioclase, quartz, apatite, zircon and opaque minerals. Carbonate porphyroblasts are common. Rutile and ilmenite aggregates are indicative of phyllitic alteration.

The high fragment/matrix volume ratio (>1) of the coarse grained pyroclastic deposits of southwestern Hyers Island and southwestern Lynx Bay in contrast to the low (<1) fragment/matrix volume ratio of the few peripheral coarse grained fragmental rocks suggests

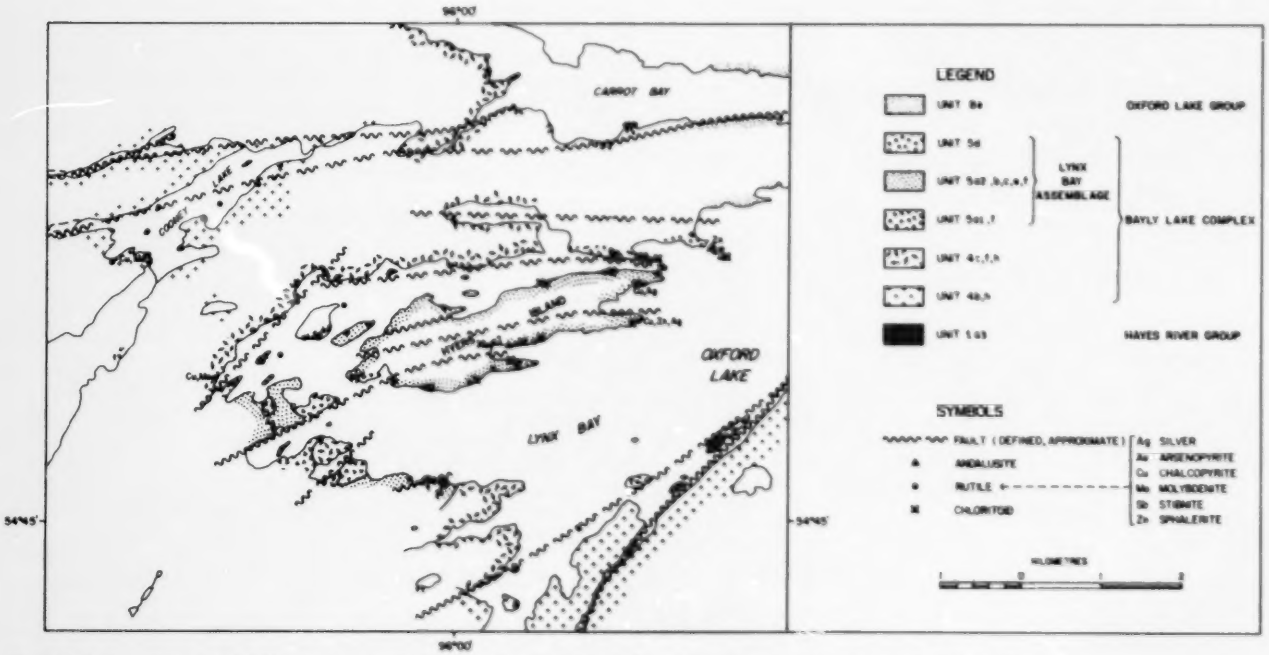


Figure 26: Location of sulphide showings, distribution of rutile, chloritoid and andalusite and geology of the Lynx Bay area.

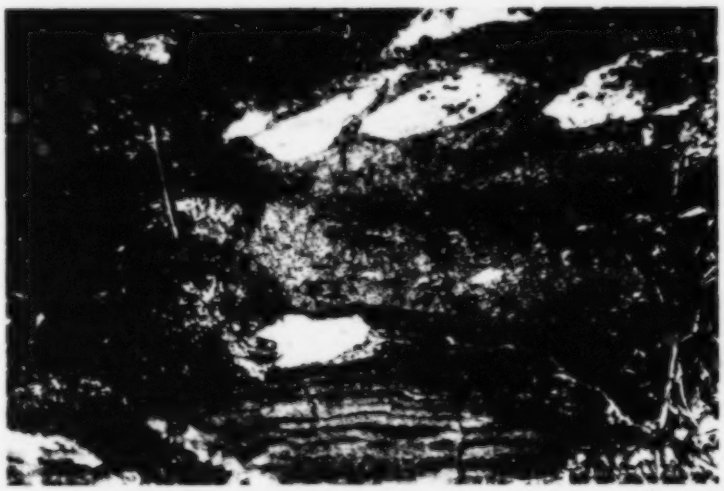


Figure 27:
Laminated lapilli-tuff (unit 5b) with isolated bombs at southeastern Hyers Island. Note slumped fragment in centre and discordancy between layering and foliation.

that the main volcanic centre is located near the southwestern peninsula of Hyers Island (Fig. 26). This zone contains a 360,000 tonne chalcopyrite-pyrite body, averaging 2.50% copper (Haskins and Stephenson, 1974).

A breccia with a dark, fine grained matrix occurs in the northeast corner of the rectangular bay on the southern shore of central Hyers Island. The host rock is a carbonatized volcanic breccia cut by brown-weathering carbonate veins. The breccia fragments are similar to the host rock and may include carbonate. In some places it is evident that the wall rock was shattered, as fragments and wall rock display a jigsaw crack pattern along which the matrix intruded. This breccia is interpreted as a late vent breccia which postdated the hydrothermal carbonate-quartz veins.

Minor occurrences of water-reworked pyroclastic rocks occur at southern Hyers Island. They differ from the pyroclastic rocks by their greater compositional variety, a higher degree of roundness of the fragments and a sorted matrix. Sediments related to the volcanic rocks occur just northeast of Hyers Island (see unit 5d).

Carbonate-quartz-sulphide bodies and veins (5c)

Cross-cutting carbonate-quartz veins are abundant in the Lynx Bay assemblage and the surrounding tonalites (unit 4). There is evidence for at least two generations of veins. The older veins are closely associated with the volcanic activity, as they have associated hydrothermal alteration haloes. A phase of deformation and low-grade metamorphism, separated the emplacement of the older veins from younger veins which have no direct relationship with the volcanic activity. Mineralogically the two generations are similar. The veins are intimately associated with the disseminated and massive sulphide mineralization.

Carbonate-quartz veins are exposed over a length of 500 m and their width varies from a few centimetres to 15 m. Their margins are usually irregular. Carbonates are the major constituents. Dolomite, magnesite, and possibly ankerite, have been identified by staining and X-ray methods (Hutchinson, 1974). Rare calcite may occur as interstitial grains among other carbonates. Coarse crystalline quartz is a primary vein phase but quartz also occurs in fracture fillings. Irregular aggregates of green chlorite and disseminated fine pyrite cubes are common. Veins with higher amounts of sulphides (approximately 20 vol.%) exhibit an anastomosing framework of sulphide enclosing mosaics of quartz and carbonate.

A chalcopyrite-bearing quartz-chlorite-mica veinlet at southern Hyers Island contains chloritoid. Chloritoid and andalusite also occur in the adjacent quartz-sericite-chlorite host rock (Fig. 26). Thin section examination suggests two phases of deformation and metamorphism postdated the emplacement of the veinlet. The younger foliation cross-cuts the carbonate veinlets.

A stibnite-bearing carbonate-quartz vein at the northeastern tip of Hyers Island (Fig. 26) postdated a phase of deformation during which the volcanic rocks were transformed into quartz-carbonate-sericite-chlorite schists. Quartz is the major vein phase. The carbonate phase is magnesite. Fibrous dravite forms locally columnar aggregates. Stibnite and pyrite occur in the vein, and are disseminated in the host rock at greater depths (Haskins, pers. comm.).

Hydrothermal alteration: Interaction of carbonate-quartz-sulphide veins and pyroclastic rocks

Original features of the pyroclastic rocks of the Lynx Bay area were obliterated by alteration caused by carbonate-quartz veins. Only quartz phenocrysts survived the alteration. Different stages of the alteration are exposed on the shore opposite southwestern Hyers Island where veins cut weakly layered porphyritic lapilli-tuffs. The subrounded lapilli and the matrix have similar compositions. The veins (2 to 5 cm wide) are mainly composed of a brown-weathering magnesite or dolomite which contains rare pyrite cubes. The following alteration pattern was documented in the host rock (Fig. 28):

- carbonate-quartz vein
- chloritization zone
- carbonatized zone
- white bleaching zone
- unaltered lapilli-tuff

} altered lapilli-tuff

The carbonatization associated with carbonate-quartz veins may also form large-scale alteration zones of reddish-pink quartz-carbonate-sericite-chlorite schist.

Quartz wacke, conglomerate, minor greywacke and argillite (5d)

Sediments derived from the volcanic rocks of unit 5 occur northeast of Hyers Island. Most abundant is a light brown to reddish-pink schistose quartz wacke, which is mineralogically similar to the quartz-chlorite-sericite-carbonate schists described above. Agglomerate and

crystal tuffs are interlayered with wackes, at western Lynx Bay, suggesting that volcanic activity was contemporaneous with sedimentation. The wackes contain abundant blue opalescent quartz grains set in an aphanitic matrix. The quartz grains are relict phenocrysts of the porphyries and porphyritic tonalites of unit 4 and the fragmental rocks of unit 5.

In thin section the quartz grains of the wackes are angular to subrounded (1 - 5 mm), partly with an internal mortar texture. Post-tectonic euhedral chloritoid and chlorite porphyroblasts occur locally. The matrix consists of sericite, quartz, limonite, carbonate grains with limonite coating, and leucoxene.

The quartz wackes vary in grain size and beds with cobbles as large as 15 cm are common. Graded sequences as follows were recorded:

- Conglomerate with tonalitic porphyry cobbles
- Argillite
- Chert
- Medium grained wacke
- Coarse grained quartz wacke
- Conglomerate with cobbles of milky quartz, brown-weathering carbonate and smeared and stretched-out slivers of chlorite-rich material.

The presence of abundant vein-quartz and vein-carbonate boulders (up to 30 cm) in the conglomerates and the quartz wackes suggests that the quartz-carbonate veins were exposed and eroded simultaneously with the porphyritic tonalites and yet these wackes are cut by numerous (up to 30 cm wide) quartz-carbonate veins (Fig. 29), implying either a long period of emplacement of quartz-carbonate veins, or the existence of two vein generations. Available evidence supports the latter alternative (see below).

The discordant quartz-carbonate veins have locally caused extensive, stratabound, apparently selective introduction of carbonate into the sediments, particularly into finer grained wacke. Concordant brown-weathering carbonate layers clearly branch off the discordant veins, resulting in a conspicuously banded, carbonatized wacke (Fig. 30). Similar concordant carbonate layers occur in the conglomerates.

Quartz wackes, arkosic wackes and conglomerate (5d) occur also at Brogden Lake (eastern Carrot River) on strike with the Hayes River Group rocks of the Carrot River belt. The rocks are highly sheared, and mylonitized contacts indicate that the rocks of the Lynx Bay assemblage and the Hayes River Group are tectonically interleaved.

Chloritoid-bearing quartz-carbonate-chlorite-sericite schists (5e)

These highly fissile schists underlie the numerous shear zones on Hyers Island and in northern and northwestern Lynx Bay. They may have been derived from pyroclastic rocks (units 5a and b), quartz-plagioclase porphyries (4g) or quartz wackes (5d) by intense tectonization and chemical alteration.

Schists with green knots of chloritoid porphyroblasts occur along the northeastern and southwestern shores of Hyers Island. Gossan zones are common.

The schists display an older schistosity that is folded and transposed into a younger near-parallel shear zone, indicating at least two phases of deformation.

In thin section, the rocks are made up of lenticular aggregates of aphanitic to medium grained carbonate and green chlorite. The matrix consists of aphanitic quartz, sericite and minor chlorite, carbonate, leucoxene, hematite, pyrite, zircon and local rutile. Chloritoid forms randomly oriented, euhedral, non-strained porphyroblasts, up to 2 mm, with straight inclusion trains, or subsequently rotated porphyroblasts that predate a well developed younger foliation. Leucoxene-rutile aggregates were deformed in the foliation planes, but retained their original shape in the chloritoid porphyroblasts.

The sieve-textured chloritoid blasts include sugary aggregates of dirty brown carbonate, in contrast to the matrix carbonate which is clear and colourless. The chloritoid is partially replaced by clear carbonate, chlorite and quartz, and is cut by discordant veinlets of colourless carbonate and quartz which postdate the foliation. The rotated anhedral chloritoid contains no sugary dirty brown carbonate inclusions; it is partially broken down to clear carbonate, hematite, quartz and chlorite. The microstructures thus indicate that chloritoid was formed after a first deformation phase, as part of a stable mineral association that included chlorite, quartz and brownish carbonate. Subsequently chloritoid became unstable during a second deformational phase, which was accompanied or preceded by the introduction of colourless carbonate.

Diabase (5f)

The diabase dykes are black to dark green, massive, fine- to medium-grained rocks. They have irregular outlines, are generally strongly sheared and strike east parallel to the regional structure. Chilled margins are locally preserved.

Figure 28:
Carbonate vein (unit 5c) with adjacent dark grey blotchy chloritization, carbonatization and white bleaching zone on the left-hand side, respectively, in lapilli tuff (unit 5b). Note the sharp colour contrast between the carbonatization and the bleaching zone; Western Lynx Bay.

Figure 29:
Carbonate-quartz veins (unit 5c) in quartz wacke (unit 5d); northeast of Hyers Island.

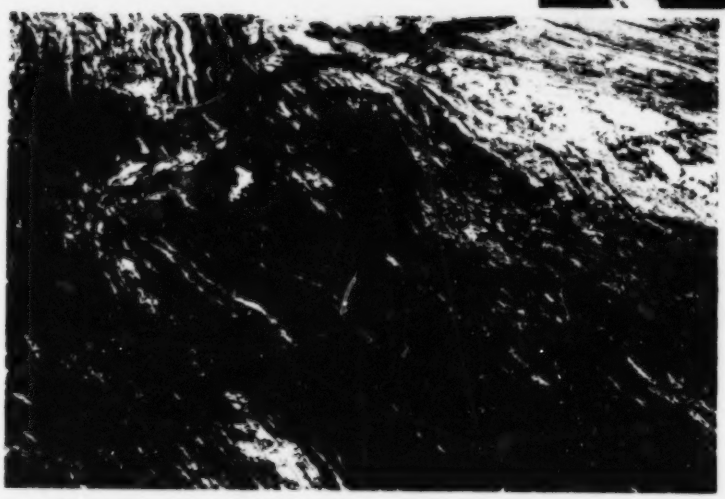


Figure 30:
Carbonatized wacke; dark grey bands in centre are carbonate. White bands are quartz. Medium grey areas, particularly on right-hand side are less carbonatized wacke; northeast of Hyers Island.

The primary mineralogy has been replaced as a result of hydrothermal alteration and low-grade metamorphism. However, ophitic textures are preserved in less deformed portions. The rocks consist of saussuritized plagioclase, colourless to light green amphibole pseudomorphs ($\gamma \wedge c = 17°$, $\delta = 0.015 - 0.018$) after pyroxene, and green chlorite. Quartz forms interstitial blebs and local graphic intergrowths with plagioclase. Sphene skeletons formed after ilmenite, and rutile aggregates as an alteration product of mafic minerals.

The diabase dykes cut quartz-carbonate veins, but are in turn truncated by similar veins, which produced sulphide enrichment near the diabase-vein contact. The diabase dykes contain sporadic xenoliths of fissile, tectonized quartz-carbonate-chlorite-sericite schist (unit 5e), related to the older carbonate-quartz veins, thus providing evidence for two generations of quartz-carbonate veins.

Petrogenetic implications of chloritoid, andalusite, rutile and carbonate

Chloritoid forms only in rocks of a limited compositional range such as iron- and alumina-rich metasediments. The presence of chloritoid in the originally andesitic, dacitic and tonalitic rocks of Hyers Island thus indicates chemical alteration during hydrothermal alteration and associated sulphide mineralization prior to the regional metamorphism.

Franklin et al. (1975) report abundant chloritoid from the footwall rhyolite of the Mattabi massive copper-zinc sulphide deposit. The coarsest chloritoid occurs in the centre of the alteration zone in cross-cutting carbonate-quartz veins. Andalusite is most abundant immediately underneath the ore and in veins of the footwall rocks.

The chloritoid occurrences are confined to a northeasterly-trending zone of about 1 x 4 km, covering the eastern half of Hyers Island and the extreme southern portion of the Carrot Point peninsula (Fig. 26). Rare chloritoid schists were also documented in the Lynx Bay assemblage at Brogden Lake.* The andalusite occurrence is located in the central part of the chloritoid zone. Dextral displacements of the fault-bounded blocks underlying Lynx Bay may have been responsible for a northeasterly deflection and extension of the chloritoid zone, which originally may have been about 1.5 km long. The volcanic strata in the Lynx Bay area indicate younging forwards the east. Thus, assuming that the chloritoid zone represents the altered footwall of a possible Mattabi-type deposit, sulphide mineralization is to be expected east and southeast of Hyers Island. Indeed, Wright (1932) reports an island (presently submerged) off the northeast end of Hyers Island that carries "enough chalcopyrite and gold to make a copper-gold ore". Drilling was undertaken during the 1920s but the work was terminated due to a rise in the water level. The drill results are

*This lake is spelled incorrectly as 'Brodgen' Lake on Map GP83-1-4.

not known. Two 10 lb. samples, taken from high-grade lenses in the exposed part of the mineralized zone, averaged 0.25 ounces/ton gold, 2.94 ounces/ton silver and 5.28% copper (Wright, 1932). Recent assayed drill core (Haskins and Stephenson, 1974) of a mineralized zone on the east end of the island yielded considerably lower metal values.

Rutile is ubiquitously present in the hydrothermally altered subvolcanic and supracrustal rocks of units 4 and 5 in the Lynx Bay area (Fig. 26).

Sub-microscopic rutile appears as single grains and as pseudomorphic aggregates in porphyries, pyroclastic rocks, mafic dykes and the chloritoid schists. The aggregates (up to 0.7 mm) have monoclinic or orthornombic outlines (Fig. 31), are locally rimmed by ilmenite and may have apatite inclusions. Chlorite-sericite-rutile-carbonate-apatite aggregates are common and resemble those described as pseudomorphs after mafic minerals in the alteration haloes of the disseminated sulphide mineralization systems farther to the west. Such replacements are typical for Andean-type porphyry copper deposits (Camus, 1975). The pseudomorphic rutile aggregates are pretectonic, as they predate the foliation, which in turn is postdated by the non-strained chloritoid porphyroblasts (Fig. 31). The formation of rutile was presumably related to the alteration process that led to the formation of the disseminated sulphide mineralization. Propylitic and phyllitic alteration, as documented around the disseminated sulphide mineralizations at Cooney Lake and western Lynx Bay, are also common features in the Hyers Island country rock, implying that the alteration haloes extended well into the supracrustal rocks that presently underlie Hyers Island.

Chloritoid occurs in supracrustal and subvolcanic rocks (Fig. 26) at Hyers Island. It is not reported as an alteration product in Andean porphyry copper deposits (Lowell and Guilbert, 1970), nor has it been identified in the alteration haloes of the disseminated sulphide mineralizations of Lynx Bay and Cooney Lake. This supports the assumption that the formation of chloritoid resulted from near-surface alteration (perhaps related to the formation of a massive sulphide deposit).

Dolomite, magnesite, calcite and possibly ankerite were recognized at Hyers Island. Chemical analyses and thin section study indicate that chloritoid becomes unstable with the introduction of magnesium carbonates. Siderite was not positively identified. However, the sulphide distribution is not related to the carbonate distribution, which could mean that introduction of the carbonates preceded the sulphide mineralization. Thus, the absence of siderite enrichment in the carbonate-rich country rocks of Hyers Island does not rule out a favourable sulphide mineralization environment.

Geological synopsis of the Lynx Bay area

The Hyers Island-Lynx Bay area is underlain by an intensely faulted, east-facing volcanic-plutonic crustal section (Fig. 26). Hyers Island and western Lynx Bay are underlain by remnants of a felsic to intermediate pyroclastic edifice with associated peripheral volcanogenic sediments. The proximity of a centre of volcanic activity is reflected by an inner vertical zone of pyroclastic breccia, flanked by finer grained pyroclastic rocks, that "connects" the disseminated sulphide mineralization of the plutonic and sub-volcanic rocks of western Lynx Bay with the near-surface chloritoid alteration in the supracrustal rocks of Hyers Island.

The porphyry copper-type mineralization and propylitic alteration at western Lynx Bay and Cooney Lake occurred contemporaneously with the intrusion of carbonate-quartz veins and associated near-surface alteration in the pyroclastic rocks that eventually led to the formation of chloritoid schists. The appearance of rutile in the plutonic, sub-volcanic and supracrustal rocks is the most conspicuous result of the propylitic alteration.

Chloritoid and andalusite were formed in the altered pyroclastic rocks during an early orogenic phase, which was followed by the intrusion of a mafic dyke swarm. Subsequent emplacement of a second set of quartz-carbonate-sulphide veins caused considerable change in the chemical composition of the host rocks by introduction of calcium and magnesium carbonates, that resulted in the breakdown of chloritoid. The stibnite-bearing vein on the former New Falu claim on the northeastern tip of Hyers Island (Haskins and Stephenson, 1974) is part of the younger vein system. The chalcopyrite-pyrite deposit on southwestern Hyers Island (former Allcop Mines Limited Claim Lynx 34), also appears to be controlled by the older carbonate-quartz veins.

The second orogenic phase resulted in the breakdown of andalusite, rotation and partial breakdown of chloritoid, and isoclinal folding of the older carbonate quartz veins, the foliation and the diabase dykes. Dextral and subsequent sinistral fold movements are the last major tectonic events.

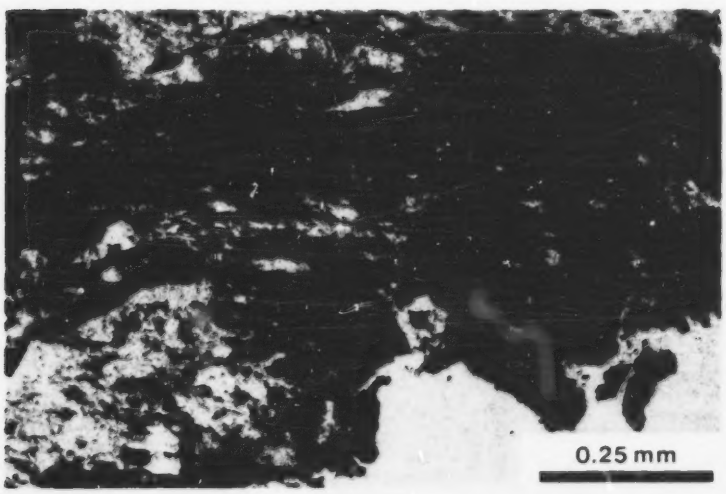


Figure 31:
Syn-tectonic chloritoid porphyroblasts and pre-tectonic hypidiomorphic rutile aggregate in quartz-carbonate-chlorite-sericite schist (unit 5e); Hyers Island.

UNIT 6: GNEISSES AND GNEISSOID ROCKS OF MAINLY TONALITIC COMPOSITION; MINOR GABBRO, HORNBLENDITE, CLINOPYROXENITE AND AMPHIBOLITE

Layered gneisses of generally tonalitic composition are part of a tonalitic gneiss-granodiorite-granite migmatite complex that is situated south of Oxford Lake in the area between Cat Eye Bay, the Washikamow River, Max Lake and Michikinabish Lake. The complex extends eastwards towards the Munro Lake area (Gilbert, in prep.; Elbers, in prep.). This migmatite terrain and a similar complex north of Carrot Bay (Oxford Lake) in the western Semple River area, are made up by rocks of units 6, 7 and 11. Hornblendites, clinopyroxenites and amphibolites are characteristic constituents of the migmatite complex.

The layered tonalitic gneisses of the Windy Lake area are separated from the Hayes River Group by tonalites of unit 4. The gneisses underlie large, over 30 kilometres long, east-trending zones, intruded by younger sheets of foliated granodiorite (7b). The large-scale lithological layering in this gneiss-granodiorite complex trends parallel to the greenstone belt to the north. The complex is intruded by a granite-granodiorite-diorite pluton (unit 11) in the Windy Lake area. The external shape and the internal structure of the granite pluton is discordant to the east-trending structures of the older rocks.

Layered tonalitic to granodioritic gneiss with concordant amphibolite layers (6a)

A conspicuous gneissic layering and common amphibolite, hornblendite and clinopyroxenite interlayers distinguish the gneisses of unit 6 from the foliated and generally monotonous but mineralogically similar tonalites of unit 4 (Fig. 22).

The gneisses are fine- to medium-grained, recrystallized and display a metamorphic layering defined by white, grey to pink quartz-plagioclase aggregates and greenish-black biotite-amphibole-clinozoisite aggregates. The width of the compositional banding may vary from a few millimetres to about 3 cm. Primary potassium feldspar is a minor phase. Secondary potassium feldspar is often present in veinlets and as a replacement mineral. Sphene and apatite are common accessories.

Enclaves of randomly oriented and weakly foliated tonalite (4) occur sporadically within the layered gneisses. Contacts between the different textural types are gradational and were documented between Lynx Bay and the Washikamow River. It is assumed that the tonalites and the layered tonalitic gneisses belonged to the same batholith.

Amphibolite (6b)

The amphibolite is fine grained, lustrous, black, well foliated and occurs as concordant bands in the tonalitic gneisses. The amphibolite may have originated as diabase or as basaltic xenoliths derived from the Hayes River Group; it is identical to the amphibolite (4j) that occurs in tonalites of unit 4 which may include both metadiabase and metabasaltic xenoliths. The amphibolite is distinguished from hornblendite and clinopyroxenite of unit 6f by its grain size, mineralogical composition and the well developed nematoblastic fabric. It contains appreciable amounts of plagioclase, quartz, and biotite in addition to green hornblende, minor epidote and accessories such as sphene, epidote and opaques, whereas hornblendite and clinopyroxenite contain only minor amounts of quartz and plagioclase.

Hornblendite and clinopyroxenite (6f)

The rocks of this unit are interlayered with the tonalitic gneisses of unit 6a, and form rare xenoliths in the tonalites of unit 4 near the Hayes River inlet. Small, outcrop-size bodies of hornblendite and clinopyroxenite are most common. A larger body near Seekowsueenik Point strikes parallel to the regional structural trend over a distance of at least 11 km and a width of up to 450 m. A smaller lens is situated 1 km to the south.

The hornblendite and clinopyroxenite are fine- to coarse-grained, black to dark green, lustrous rocks.

Despite a distinct contrast on the outcroup between the hornblendites and the tonalitic gneisses, thin section inspection reveals a complete compositional transition ranging from melanocratic biotite-hornblende tonalitic gneiss to hornblendite and clinopyroxenite. The presence of clinopyroxene (diopside) is attributed to a higher metamorphic grade.

The texture of the hornblendites varies from well-foliated nematoblastic to equigranular granoblastic. Tabular blue-green to green hornblende, commonly rimmed by light green amphibole, may contain cores of light green diopside, which is generally partially replaced by aggregates of yellow pleochroic epidote, opaques and amphibole. Hornblende-diopside intergrowths are common. Rare clinopyroxenites with over 90 vol.% diopside have a distinct equigranular granoblastic texture. Quartz and sericitized plagioclase (andesine) are abundant in the melanocratic tonalitic gneiss, but occur as interstitial grains in the hornblendites and clinopyroxenites. Red-brown biotite may be replaced by chlorite, leucoxene and potassium feldspar. Sphene and apatite are accessory phases.

The close association of the hornblendite and clinopyroxene with the tonalitic gneisses suggests a common evolution for both units. The high proportion of calcium minerals, like hornblende, epidote, sphene, diopside and apatite, does not suggest an igneous composition. The sporadic association of hornblendite with granodiorite and granite of unit 7 could indicate that both rock types were derived by remobilization of a common source, e.g., the tonalitic gneiss, and subsequent separation of the felsic from the mafic fraction.

Alternatively, hornblende and clinopyroxenite may represent enclaves of mafic volcanics of the Hayes River Group.

UNIT 7: METAMORPHOSED INTRUSIVE ROCKS OF MAINLY GRANODIORITIC COMPOSITION; GRANITE AND TONALITE; MINOR SYENITE

The rocks of this unit constitute several sheet-like bodies in the tonalites and tonalitic gneisses of units 4 and 6. The members of unit 7 range in composition from tonalite to granite, but granodiorite is the prevailing rock type. Rare field relationships indicate that unit 7 is younger than unit 4 but older than the Oxford Lake Group. The major occurrences are the Cat Eye Bay tonalite, the Hargreaves Lake granite and the Back Lake granodiorite. Smaller granite bodies were documented in tonalite (unit 4) in the Hayes River area between Oxford Lake and Windy Lake.

Tonalite, granodiorite and porphyritic granodiorite, Cat Eye Bay tonalite-granodiorite (7b)

This unit underlies a 1 to 2.5 km wide zone, which extends from Cat Eye Bay to Michikinabish Lake and west to Magill Lake (Gilbert, in prep.). The Cat Eye Bay tonalite intrudes the Hayes River Group and the older tonalitic rocks of units 4 and 6, and was eroded during the deposition of the Oxford Lake Group sediments. The regional structure at southern Oxford Lake suggests that unit 7b was intruded at moderate to shallow depth as a horizontal sheet, separating the older tonalites and gneisses of units 4 and 6 from the supracrustal rocks.

The Cat Eye Bay tonalite is white-weathering, fine- to medium-grained, weakly foliated to massive, with greyish fresh surface. Porphyritic granodiorite locally forms the northern margin of the pluton at Cat Eye Bay. Sporadic 1 to 2 cm wide reddish pink zones of potassium feldspar enrichment occur along fractures. The pink zones are surrounded by about 2 cm wide epidote-enriched zones in which biotite was altered.

Plagioclase (An_{23}) is saussuritized. The matrix is mainly made up of quartz, plagioclase, microcline, greenish-brown biotite, epidote and some muscovite, and chlorite, depending on the metamorphic grade. Characteristic accessory minerals are reddish pleochroic sphene, brown metamict allanite, apatite, leucoxene, magnetite and other opaques. Pseudomorphic chlorite-epidote-sphene aggregates after primary mafic phases (such as reported from hydrothermally altered unit 4 tonalites), are still detectable even after lower amphibolite facies grade metamorphism. The mafic aggregates are internally recrystallized and chlorite is partially replaced by biotite.

Dykes of the Cat Eye Bay tonalite cut the volcanics of the Hayes River Group and the tonalites of unit 4 in several localities, providing age relationships between unit 7 tonalite and the mylonitization and the metamorphism of the older Hayes River Group volcanics, unit 4 tonalites and their hybridization products. A layered sequence of mylonitized basalt, porphyry (4f) and hybrid garnet-biotite gneiss (4g) in western Cat Eye Bay is cut by tonalite dykes of unit 7 (Fig. 25), which clearly postdate the mylonitization and the garnet-grade metamorphism that affected the older rocks. However, unit 7 provided detritus for the sedimentary subgroup of the Oxford Lake Group, which in turn was affected by a cycle of deformation and metamorphism. The recognition of two cycles of deformation and metamorphism, separated by a period of uplift, erosion and sedimentation, is based primarily on these relationships observed in the Cat Eye Bay area (see Metamorphism).

A situation identical to that of Cat Eye Bay occurs on an island 1.3 km northeast of High Rock Island, where a gneissoid tonalite (7) sill was documented in a sequence of mylonitized hybrid and fuchsite-bearing gneisses (4g, 2e). The separation of this occurrence from the Cat Eye Bay area can be explained by a left-lateral displacement of about 8 km along an east-trending fault that underlies Oxford Lake south of Kisetpiskanak Island and north of High Rock Island and Cat Eye Bay. Evidence for the sinistral nature of this wrench fault was also found in Lynx Bay.

Back Lake granodiorite

A few scattered outcrops of granodiorite occur on the east shore of Back Lake. Relationships with surrounding rock units are not exposed, but dykes of similar granodiorite were mapped in the Hayes River Group basalts at southern Back Lake.

The granodiorites are pink to pinkish-orange, fine- to medium-grained, gneissoid and non-porphyritic. The dykes are creamy pink, fine grained and weakly porphyritic. Three modal compositions are plotted in Figures 32 and 33.

In thin section the granodiorite contains slightly sericitized, polysynthetically twinned plagioclase (An_{14}), cross-hatched, locally myrmekitic microcline and quartz in a matrix of biotite, muscovite, epidote, chlorite, quartz, and feldspar. Reddish pleochroic sphene, ilmenite and magnetite are accessories.

The northernmost outcrop of granodiorite on Back Lake contains amphibole-rich, black-pink speckled monzodioritic schlieren. In thin section they contain potassium feldspar, slightly sericitized plagioclase, bluish-green amphibole and minor biotite, chlorite, quartz, and minor reddish pleochroic sphene, epidote and apatite. Sphene is partially replaced by red-brown opaque, hematite-like material. Aphanitic, randomly oriented aggregates of red-brown biotite occur in aggregates with epidote. The Back Lake granodiorite is part of a multi-phase pluton which also includes syenite. The pluton underlies most of the area north and west of Knee Lake and is interpreted as part of unit 7 by Gilbert (in prep.).

Granodiorite, granite and porphyritic granite, Hargreaves Lake granite (7c)

Granitic rocks that postdate the tonalites (4) were formed around Hargreaves Lake (south of Carrot River) and in the Hayes River area south of Pinapankos Narrows. Unit 7c granodiorites occur in tonalitic gneisses of unit 6 in the Windy Lake area.

The granite is pink, medium- and coarse-grained, white to pink weathering with creamy white porphyritic phases, that contain quartz, plagioclase and potassium feldspar phenocrysts. It is generally weakly foliated, but north of Hargreaves Lake it has been transformed into quartz-sericite schists.

The major constituents are quartz, albite, microcline and biotite. Modal compositions are shown in Figures 32 and 33. Hydrothermal alteration in the granite south of Peridotite Island led to an increase of the quartz content to 66 vol.%. The feldspars and particularly biotite are replaced by a new mineral assemblage that may include chlorite, sericite, potassium feldspar, epidote, ilmenite and carbonate due to hydrothermal alteration. Disseminated pyrite is a common accessory of the altered granites. Primary microcline displays normal "checkerboard" twinning. Secondary potassium feldspar, however, exhibits a fine, somewhat obscure cross-hatching. Advanced stages of hydrothermal alteration are characterized by patchy potassium feldspar replacement of primary microcline and albite. Biotite is replaced by aggregates consisting of either secondary fine grained chlorite, or sericite and opaque minerals. A different type of alteration exhibits sericite development in fracture systems that cut across the primary texture, and affect albite along twinning planes. Similar mineralogical changes have been reported from alteration zones around porphyry copper systems (Lowell and Guilbert, 1973).

Dykes of fine grained, gneissoid, pinkish granite cut the tonalitic gneiss-amphibolite complex (units 4 and 6) in the Hayes River area south of the Oxford Lake greenstone belt. The rocks contain abundant potassium feldspar, plagioclase (An_{15}) and quartz (Figs. 32, 33). Potassium feldspar is partially replaced by myrmekite. Minor constituents are dark greenish brown biotite, yellow pleochroic epidote, bluish green amphibole, muscovite and reddish pleochroic sphene.

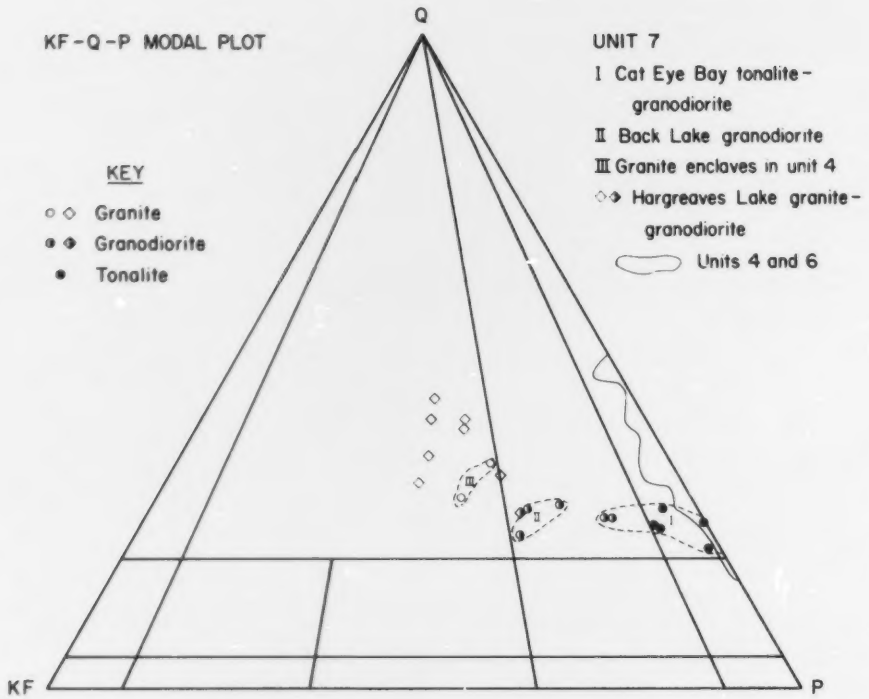


Figure 32: Potassium feldspar-quartz-plagioclase modal plot for unit 7. Black symbols: tonalite; black-white symbols: granodiorite; white symbols: granite.

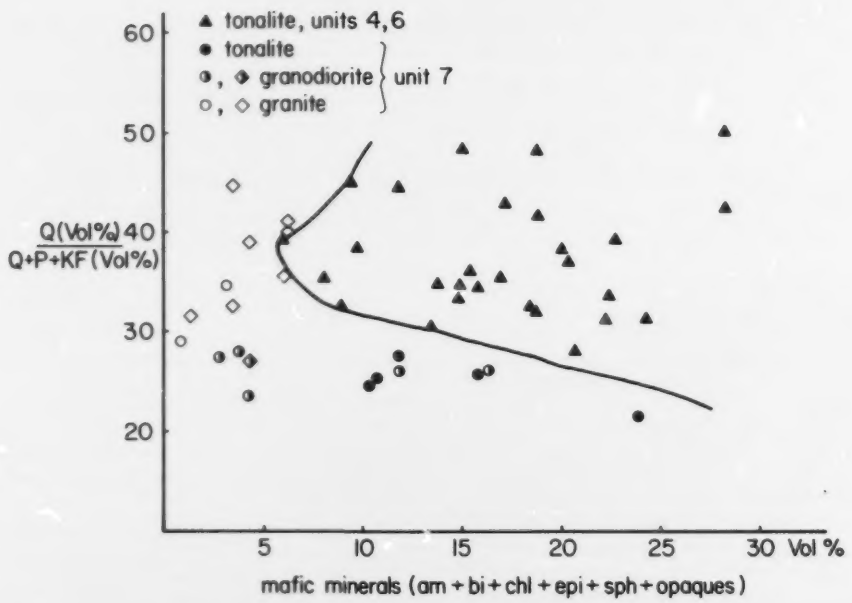


Figure 33: Mafic minerals versus quartz/feldspar ratio modal plot for units 4, 6 and 7.

THE OXFORD LAKE GROUP (UNITS 8, 9 AND 10)

Introduction

DEFINITIONS

The Oxford Lake Group comprises an older mainly volcanic subgroup and a younger sedimentary subgroup. The volcanic subgroup includes porphyritic rocks ranging in composition from basalt to rhyolite. The sedimentary subgroup is composed of conglomerate, greywacke, arkosic sediments and minor argillite. Both subgroups are well exposed in eastern and central Oxford Lake. They underlie a northwesterly-trending synclinorial belt which reaches a width of about 20 km in eastern Oxford Lake, where the belt bifurcates into a westerly-trending arm, underlying central Oxford Lake, and a northwesterly-trending arm. The eastern extension of the Oxford Lake Group is described by Gilbert (in prep.). The northern arm is a synclinorium and is intruded by a younger granodiorite (unit 11). The westerly-trending arm pinches out towards the Carrot River and is bounded by an unconformable contact with the Hayes River Group, and possibly also by a fault, along its southern margin. Its northern margin is a fault, or possibly a zone of **en echelon** faults, which can be traced from Carrot Bay to Forestry Point. This fault underlies central Carghill Island and will be referred to as the Carghill Island fault. The bifurcation of the zone of the Oxford Lake Group appears to be caused by an upthrow of the northern block along the Carghill Island fault.

The Hayes River Group and the Bayly Lake Complex rocks formed the source for the Oxford Lake Group sediments. The Oxford Lake Group overlies the Hayes River Group unconformably. Contacts between the Oxford Lake Group and the Bayly Lake Complex are not exposed.

The volcanic subgroup occurs only locally, in an east-trending zone that includes the area between Jackson Bay and Eight Mile Point, the area east of Jackson Bay, Traverse Island, the southern part of Carghill Island, Carrot Bay and the islands between Carrot Bay and Carghill Island. The conglomerate layers of the sedimentary subgroup reach a maximum thickness of 2.4 km in the Eight Mile Point region, where they are underlain by the volcanic subgroup, suggesting a locally high relief.

Previous investigators (Wright, 1932; Barry, 1959, 1960; Campbell et al. 1972) regarded the conglomerate (unit 9) as the base of the Oxford Lake Group instead of the volcanic rocks of unit 8. The authors also gave opposing interpretations of the contact between the Hayes River Group and the Oxford Lake Group, resulting in different subdivisions of the Hayes River Group and Oxford Lake Group (Table 3).

Barry (1959, 1960) concurred with Wright (1932) that the volcano-sedimentary series can be subdivided into the Hayes River Group and the unconformably overlying 'Oxford Group'. However, Barry (1960) interpreted the fragmental rocks of central Oxford Lake, (previously mapped as basal conglomerates of the "Oxford Group" by Wright, 1932), as pyroclastic deposits, and assigned the pyroclastics to the newly-defined "Upper Unit of the Hayes River Group", thereby maintaining a two-fold subdivision into mainly volcanic and mainly sedimentary groups. Barry (1960) redefined most of Wright's Hayes River Group as the "Lower Unit of the Hayes River Group".

Thus, he re-assigned rocks previously considered to overlie the unconformity to a unit that predated the unconformity. The present study agrees with Barry's (1959, 1960) interpretation of the pyroclastic origin of the deposits of central Oxford Lake, but does not support the assignment of these deposits to the Hayes River Group. Evidence for the reassignment of Barry's (1959, 1960) "Upper Unit of the Hayes River Group" as the volcanic subgroup of the Oxford Lake Group will be presented. The previous "Oxford Group" (Wright, 1932; Barry, 1959, 1960) has been renamed as the sedimentary subgroup of the Oxford Lake Group.

Campbell et al. (1972) renamed Wright's (1932) "Oxford Group" as the "Oxford Lake Subgroup" (Table 3) and included it in the Hayes River Group, mainly because of lack of supporting evidence for an unconformity between the "Upper Unit of the Hayes River Group" and the "Oxford Group". The authors, however, overlooked the unconformable relationship between Barry's (1960) "Lower and Upper Units of the Hayes River Group".

The subdivision (Table 3) of the volcano-sedimentary belt proposed herein accommodates the following views held since Wright's (1932) earliest proposal:

1) Recognition of a mixed pyroclastic-epiclastic group, occurring between the predominantly volcanic, lower section and the sedimentary, upper section of the greenstone belt, such as proposed by Barry (1959, 1960) and Campbell et al. (1972).

2) A gradual conformable transition from the intermediate, mixed pyroclastic-epiclastic sequence to the upper sedimentary sequence, as advocated by Campbell et al. (1972).

3) An unconformity between the predominantly volcanic Hayes River Group and the younger, mainly pyroclastic and sedimentary rocks, proposed by Wright (1932) and adopted with some modifications by Barry (1959, 1960).

TABLE 3
Subdivisions of the Oxford Lake-Knee Lake-Gods Lake greenstone belt

Wright (1932)	Barry (1959, 1960)	Campbell, Elbers and Gilbert (1972)	This report
Oxford Group	Oxford Group	Oxford Lake Subgroup of the Hayes River Group	sedimentary subgroup of the Oxford Lake Group
.....	unconformity	.....	.....
basal conglomerate	Upper unit of of the Hayes River Group	Knee Lake Subgroup of River Group	volcanic subgroup of Oxford Lake Group
unconformity	.....	.....	unconfomity
Hayes River Group	Lower unit of the Hayes River	Gods Lake Subgroup of the Hayes River Group	Hayes River Group

UNCONFORMITIES

Wright (1932) first reported an unconformity between the Hayes River Group and the Oxford Lake Group: "the character and relations of the basal beds of conglomerate indicate that the Hayes River lavas and sediments were being eroded at the time the Oxford conglomerate was deposited." However he did not describe a specific location.

Sopuck (1971) found evidence for an unconformity between both groups at Red Cross Lake. A "clear and knife-sharp" unconformable contact between the Hayes River Group and the Oxford Lake Group was documented by Marten (1973) on Chataway Lake.

Barry (1960) describes an angular unconformity on the island west of Kisetpiskanak Island, where east-facing conglomerate beds of the Oxford Lake Group overlie generally north-facing pillow lavas of the Hayes River Group (Fig. 34). Detailed mapping at this location and the Semple Bay area (Fig. 35) showed that an angular unconformity is not evident on outcrop scale in either locality due to deformation and lack of continuous exposure. However, the regional structure in the Kisetpiskanak Island and Semple Bay areas suggests an angular unconformity. Moreover, the map-scale distribution and structure of the Hayes River Group and Oxford Lake Group also suggest an unconformable contact in the Semple Lake-Oxford Lake area. The Hayes River Group volcanics (units 1b and 2a) are part of a southeast to south-facing monocline, whereas the overlying conglomerates (unit 9b) of the Oxford Lake Group constitute the north-facing limb of an east-trending syncline (Fig. 35). The conglomerate consists of fragments of the Hayes River Group and the volcanic subgroup of the Oxford Lake Group.

The contact between the Hayes River Group and the Oxford Lake Group is exposed west of Kisetpiskanak Island (Fig. 34). The overall structure, although more complicated, resembles that of the Semple Bay area. A monoclinal sequence of Hayes River Group basalts (unit 1b) is overlain by a synclinorium comprised of Oxford Lake Group rocks, including epiclastic mafic breccias and felsic pyroclastic breccias, intercalated with tuffaceous sediments (unit 8e), which are overlain by a succession of polygenetic pebble-cobble conglomerate (unit 9b) and greywacke (unit 10a) at eastern Kisetpiskanak Island. The conglomerate, however, wedges out towards the west, as it does not outcrop between the lower epiclastic-pyroclastic sequence and the greywacke on western Kisetpiskanak Island. Late cross-folding along moderately steep west-southwesterly-plunging axes resulted in refolding of the synclinorium (Fig. 34). The monoclinal Hayes River Group sequence was left-laterally displaced along an east-trending fault and thrown up against the southern limb of the Oxford Lake Group synclinorium. The cross-folding developed prior to or during the fault movement.

The conglomerate layer at the Hayes River Group-Oxford Lake Group contact trends 20° (Fig. 34). Massive and featureless basalt directly underlies the conglomerate. Thirty metres farther west, an original layering is discernable in the basalt striking 145°. There are no top indicators between this location and the contact. The east-facing strata of the Oxford Lake Group may overlie the north-facing basalts of the Hayes River Group, south of the small bay directly south of the contact, but exposure is not continuous and the aforementioned east-trending fault is assumed to underlie this small bay. Hence, no conclusive evidence exists in this location for an angular unconformity. The overall structure, however, suggests an unconformable relationship between the Oxford Lake Group and the Hayes River Group.

The Volcanic Subgroup

In central Oxford Lake the recognition of the pyroclastic-epiclastic sequence (unit 8) as the volcanic subgroup of the Oxford Lake Group is based on structural, chemical and petrological differences between the Hayes River Group and the volcanic subgroup.

STRUCTURE AND STRATIGRAPHY

The Hayes River Group forms a simple monoclinal sequence in the Oxford Lake and Knee Lake areas, displaying folds with wave lengths in the order of 20 km, unconformably overlain by the synclinorial belt of the Oxford Lake Group. The rocks of the volcanic subgroup are considered part of the Oxford Lake Group, and younger than the unconformity, because of:

1) the similarity of the structural styles of the sedimentary upper sequence of the Oxford Lake Group (sedimentary subgroup units 9 and 10) and the volcanic subgroup;

2) the concordancy of bedding and structural elements of the volcanic subgroup and the sedimentary subgroup;

3) the gradual transition between the pyroclastic-epiclastic sequence of the volcanic subgroup and the sediments of the sedimentary subgroup.

The Hayes River Group and the volcanic subgroup of the Oxford Lake Group differ in that:

1) sediments are rare in the Hayes River Group, whereas they occur richly intercalated with the volcanic rocks of the volcanic subgroup, particularly at higher stratigraphic levels;

2) the Hayes River Group comprises several smaller distinct basalt-rhyolite cycles whereas the volcanic subgroup constitutes only a single, distinct, volcanosedimentary cycle.

PETROGRAPHY

Characteristic petrographic differences between the Hayes River Group and the volcanic subgroup of the Oxford Lake Group are listed in Table 4.

TABLE 4
Petrographic characteristics of the Hayes River Group and volcanic subgroup of the Oxford Lake Group

— Hayes River Group		volcanic subgroup of the Oxford Lake Group
— mainly aphyric — quench textures are common — commonly variolitic, locally vesicular	texture of volcanic rocks	— mainly porphyritic — no quench textures — commonly vesicular
— plagioclase	phenocrysts	— plagioclase, biotite and amphibole (generally pseudomorphic after mafic phases)
— commonly pillowed, locally massive	primary macrofeatures	— massive and fragmental, rarely pillowed
— basalt	prevailing rock type	— porphyritic andesite and porphyritic dacite

CHEMISTRY

A detailed account of the chemistry of the volcanic rocks of the Hayes River Group and the volcanic subgroup of the Oxford Lake Group is given by Hubregtse (1976, 1978). Striking chemical contrasts between the two groups are summarized in Table 5.

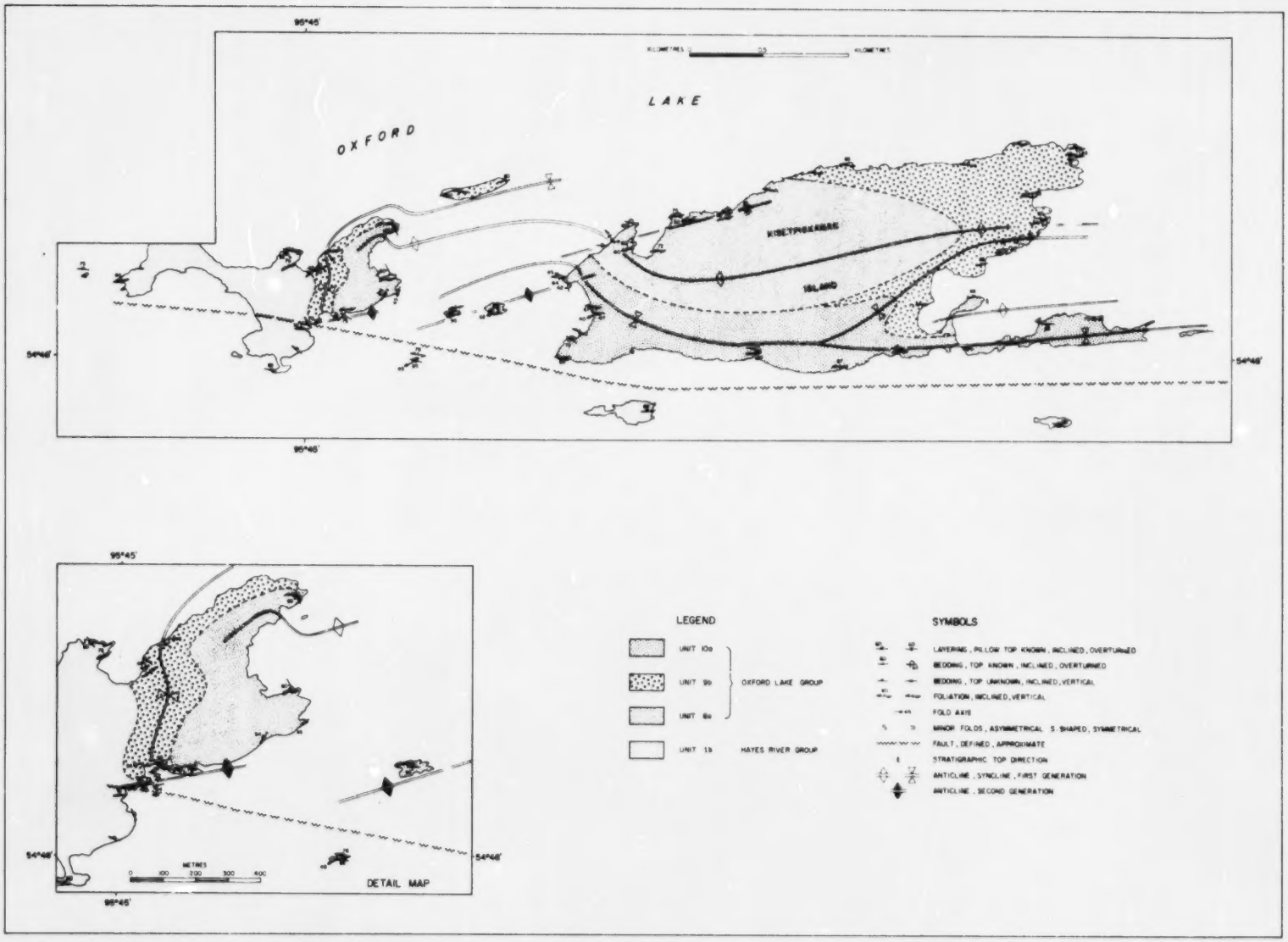


Figure 34: Hayes River Group-Oxford Lake Group relationship near Kisetpiskanak Island, Oxford Lake.

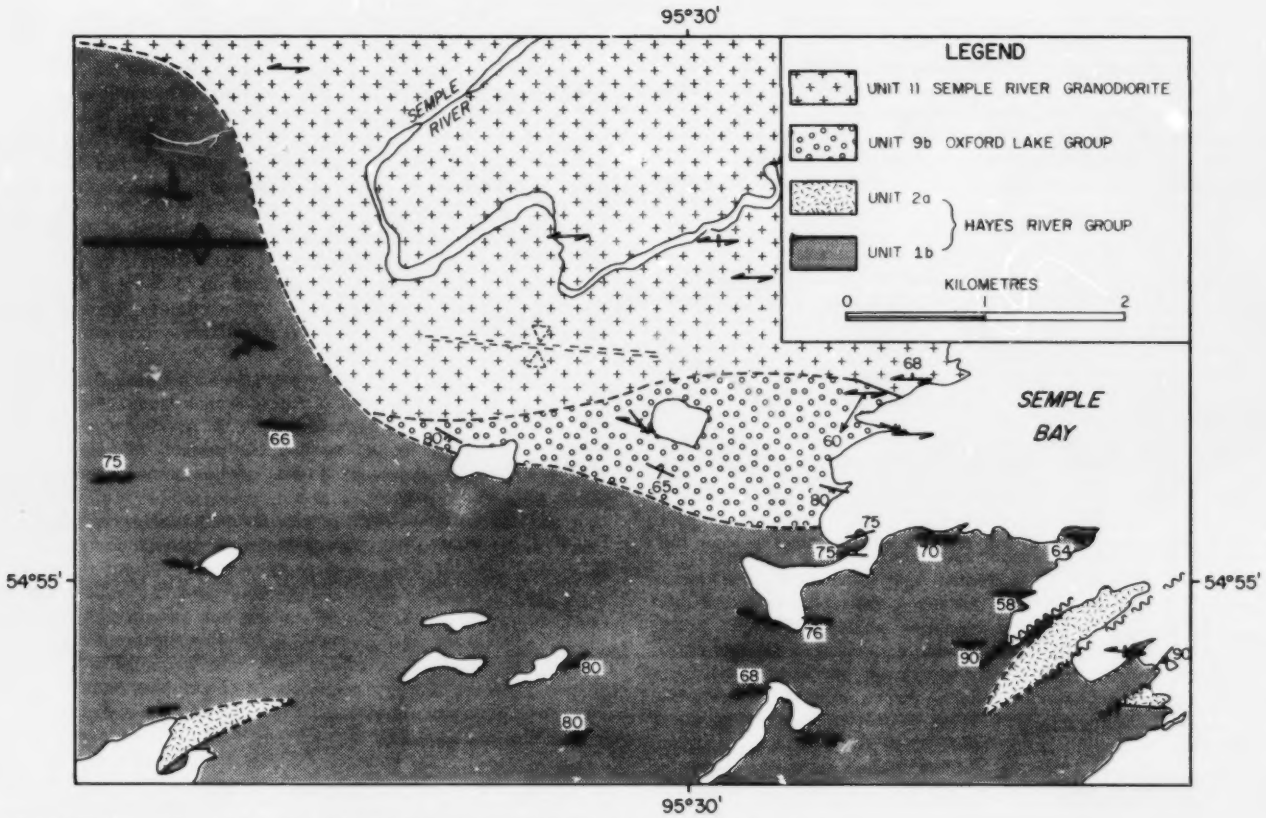


Figure 35: Hayes River Group-Oxford Lake Group relationship at Semple Bay, Oxford Lake.

TABLE 5
Chemical Characteristics of the Hayes River Group and Volcanic Subgroup of the Oxford Lake Group

	Affinity of the volcanic series	K_2O content of the mafic members	Trace element content of members with 53.5% SiO_2	SiO_2 — 1% distribution
Hayes River Group	— tholeiitic, grading into weakly calcalkaline with increasing stratigraphic height	— low potassium tholeiites average 0.27%	— ppm 76 — 373 Sr 50 — 285 Ba 4 — 30 Rb	— bimodal, with a "Daly gap" at about 61%
Volcanic Subgroup of the Oxford Lake	— compares closely to the shoshonitic association (Joplin, 1968)	— shoshonites and absarokites may contain 2.1 — 3.6%	— ppm — 370 — 870 Sr 775 — 1010 Ba 54 — 128 Rb	— unimodal with a mode at about 60%

PETROLOGY

The Hayes River Group basalts resemble low-potassium ocean floor tholeiites (Green, 1973; Hubregtse, 1976, 1978). In contrast, rocks of the shoshonitic association have been recorded in continental regions only (Joplin, 1968). The higher K_2O content of the rocks of the volcanic subgroup point to a thicker crust at the time of the emplacement of these rocks as compared to the crustal thickness at the time of the deposition of the low-potassium tholeiites of the Hayes River Group. Evidence for a thicker crust also stems from the fact that igneous rocks of units 4 and 7, which are intrusive into the Hayes River Group, are found as detritus in the conglomerates of the Oxford Lake Group, suggesting addition of tonalitic material to the crust prior to the deposition of the Oxford Lake Group. The source areas for the conglomerates must have been eroded substantially in order to expose rocks with igneous textures. Thus, a period of crustal thickening, orogenesis, uplift and erosion separated the deposition of both volcanic sequences.

The significance of the conglomerates of the Oxford Lake Group

The opposing statements by Wright (1932), Barry (1959, 1960) and Campbell et al. (1972) with regards to the contact between the Oxford Lake Group and the Hayes River Group, appear to stem from different interpretations of the ambiguous nature and position of the conglomerates in the Oxford Lake Group, in particular the stratigraphic positions of the conglomerates, as shown in a hypothetical cross-section (Fig. 36). Conglomerate layers of unit 9 at the base of the sedimentary subgroup form only locally the base of the Oxford Lake Group. In other places, for instance at Eight Mile Point, they conformably cover the volcanic subgroup, which was previously included in the Hayes River Group.

At Eight Mile Point the volcanic subgroup (unit 8) is overlain by a polygenetic conglomerate* (unit 9) (Fig. 36,C). Close to the base, up to 33 vol.% of the conglomerate is made up of detritus from the volcanic subgroup. Stratigraphically downwards the conglomerate grades into pyroclastic deposits of the volcanic subgroup without any lithological or structural break.

The depositional contact between the Hayes River Group and the Oxford Lake Group, west of Kisetpiskanak Island (Fig. 34) is marked by a polygenetic conglomerate (Fig. 36, A) which also overlies a mixed, predominantly sedimentary, but partially pyroclastic sequence, that is interpreted as the upper section of the volcanic subgroup (units 8e, 8g and 8h).

B (Fig. 36) depicts the base of the Oxford Lake Group at Semple Bay (Fig. 35) where the conglomerate is polygenetic and consists

*Classified according to K_2O and SiO_2 contents after Mackenzie and Chappel (1972).

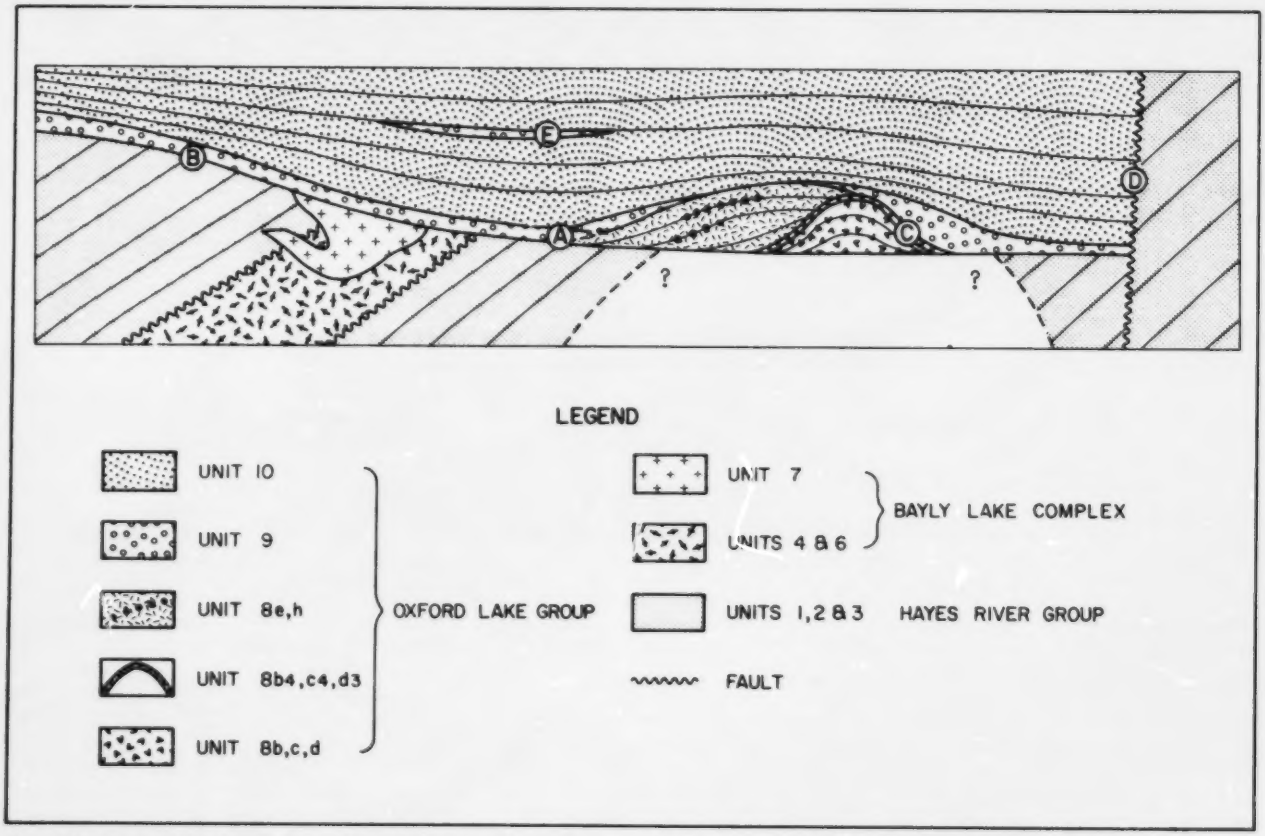


Figure 36: Hypothetical cross-section showing relationships between Oxford Lake Group and older rocks, and stratigraphic positions of conglomerates. Not to scale.

almost entirely of detrital material derived from the Hayes River Group and the Bayly Lake Complex. The contact with the Hayes River Group is unconformable.

D (Fig. 36) illustrates the Carghill Island fault along which the northern block of the Hayes River Group is thrown up against the southern Oxford Lake Group synclinorium.

E depicts the intraformational conglomerates of southeastern Oxford Lake.

Whether the entire Oxford Lake Group, including the volcanic subgroup, is underlain by a basal conglomerate remains unknown since the depositional contact between the volcanic subgroup and the Hayes River Group is not exposed.

Petrography of the volcanic subgroup of the Oxford Lake Group

UNIT 8: METAMORPHOSED PORPHYRITIC VOLCANIC ROCKS AND RELATED SEDIMENTARY ROCKS

The volcanic subgroup of the Oxford Lake Group is made up of a variety of volcanic, predominantly fragmental rocks with a conspicuous porphyritic nature. The subgroup changes compositionally in a westerly direction, from Jackson Bay to Carrot Bay, from a sequence of mainly mafic and intermediate, massive and pyroclastic rocks to a mixed sequence of intermediate and felsic pyroclastics and volcanogenic conglomerates and wackes. The volcanic subgroup at Knee Lake shows a similar lithological variety (Gilbert, in prep.).

A distinct assemblage of volcanic rocks (Hubregtse 1976, 1978) forms a separate entity within the volcanic subgroup and is exposed in the area between Eight Mile Point, Traverse Island and Jackson Bay and in the area northeast of Jackson Bay. The chemistry and petrogenesis of these volcanics were discussed earlier (Hubregtse, 1976, 1978).

The "Traverse Island sequence", a suite of pyroclastic-epiclastic successions, makes up the balance of the volcanic subgroup.

The Jackson Bay suite and Traverse Island sequence interfinger at eastern Traverse Island where porphyritic flows and dykes occur within the epiclastic-pyroclastic Traverse Island sequence. The regional structure, however, suggests that the Traverse Island sequence overlies the Jackson Bay suite. Strata of northeastern Traverse Island face away from the Jackson Bay-Eight Mile Point area, indicating that the porphyritic flows and dykes at Traverse Island represent late stages of Jackson Bay-type volcanism.

Pillowed basalt (8a)

Pillowed basalts of the Oxford Lake Group are exposed only on an island 2.5 km east-northeast of Carrot Point. The basalts are aphyric, in contrast to porphyritic volcanics of the Jackson Bay suite, and are overlain by a succession of greywacke, argillite and volcanogenic breccia of units 8e and 8h.

Shoshonite and minor absarokite (8b)
Porphyritic andesite (8c)
Porphyritic dacite and rhyolite (8d) (Jackson Bay Suite)

The most common rock types in Jackson Bay are chemically absarokites, shoshonites, high potassium-high aluminum basalts, high-potassium andesites, andesites, high-potassium dacites and dacites (Fig. 37). Based on petrographic criteria, such as the shape, nature and distribution of the phenocrysts, the Jackson Bay suite is absarokite, shoshonite, porphyritic andesite and porphyritic dacite and rhyolite. Although primary minerals are totally replaced by low-grade metamorphic assemblages, certain characteristics can still be compared with descriptions of non-metamorphosed absarokites and shoshonites (Nicholls and Carmichael, 1969).

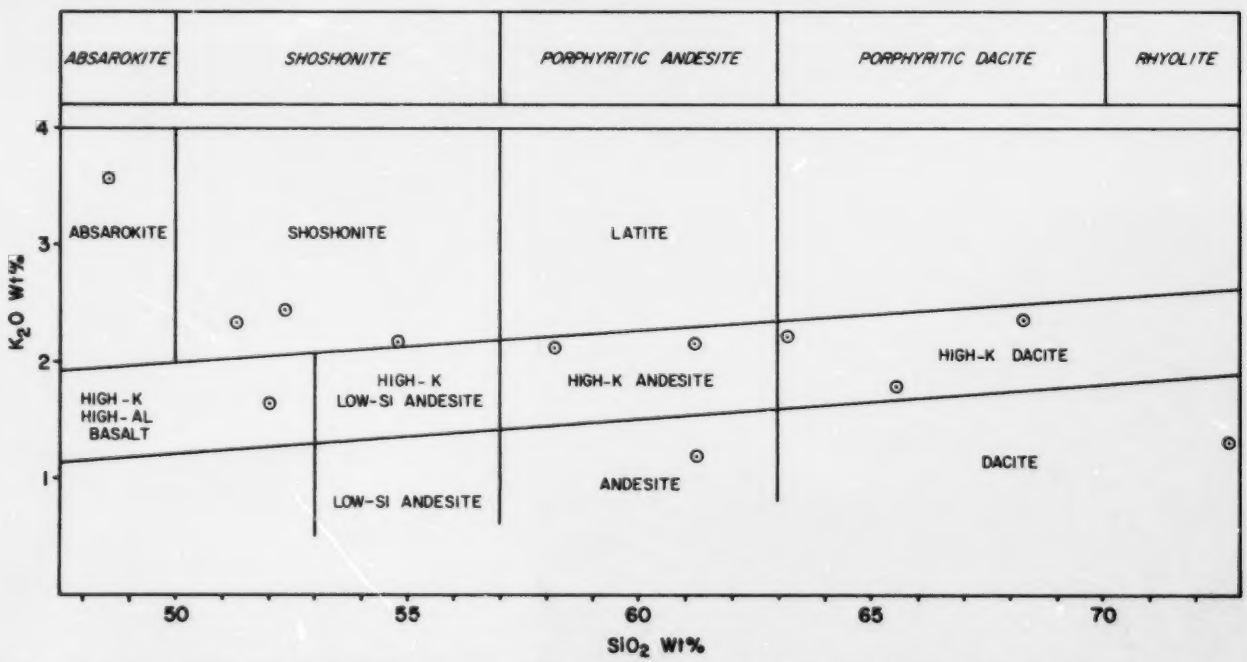


Figure 37: Chemical subdivision of potassium-rich volcanic rocks, after Mackenzie and Chappell (1972). Petrographic subdivision shown in italics.

The absarokites are dark, micaceous, lustrous, fine- to medium-grained rocks. Tiny plagioclase phenocrysts, usually smaller than 2 mm, stand out on the weathered surface (Fig. 38). In thin section, the rather stubby albite-twinned plagioclase phenocrysts may form clusters, and are commonly saussuritized, particularly in the core. In one instance clear plagioclase of 30% An was found. Non-metamorphosed absarokites in Wyoming (Nicholls and Carmichael, 1969) contain orthoclase in the groundmass and are the only members of the shoshonitic series not to have plagioclase phenocrysts, in contrast to the shoshonites which contain abundant plagioclase phenocrysts. The original groundmass orthoclase of the Jackson Bay absarokites may have reacted with a mafic phase (hornblende?) during metamorphism to form the present groundmass assemblage of biotite and albite.

The matrix of the absarokites largely consists of aphanitic biotite, plagioclase microphenocrysts, chlorite, quartz, magnetite, carbonate, epidote and allanite. Some samples are enriched in deep blue-green tourmaline. All primary features in the matrix, except the microphenocrysts of plagioclase, have been obliterated by deformation and metamorphism. Skeletal magnetite embedded in metamorphic biotite vaguely outlines pseudomorphs of undetermined mafic phenocrysts.

The shoshonites are the most conspicuously porphyritic rocks. White plagioclase tablets, up to 2 cm, stand out on a purplish, unevenly weathered surface (Fig. 39). In some instances the phenocrysts are well aligned and locally they outline an oval pattern to indicate a rolling motion within a flow. The fresh surface shows yellowish-green plagioclase phenocrysts in a green-black matrix. The plagioclase phenocrysts are twinned according to the albite law and are highly saussuritized. The recrystallized matrix is made up of biotite, chlorite, muscovite, magnetite, quartz, clinozoisite and plagioclase. The matrix contains irregular, internally recrystallized, globular aggregates (up to 5 mm) consisting of quartz, chlorite and carbonate which are interpreted as filled vesicles.

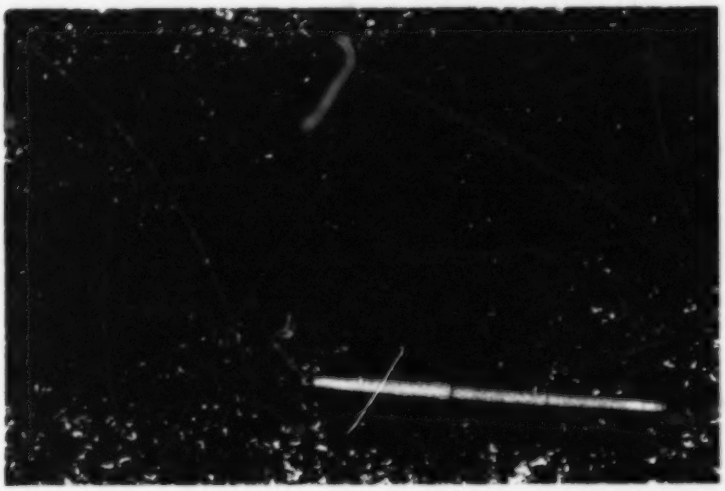


Figure 38:
Absarokite, Jackson Bay suite; 3.7 km south-southeast of Eight Mile Point.

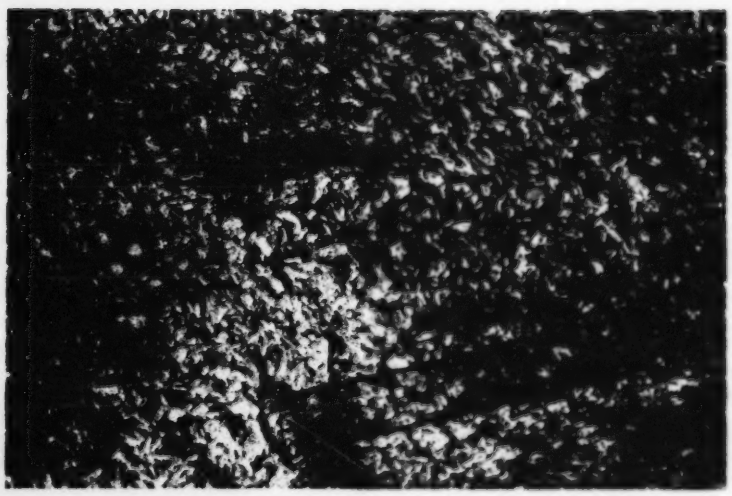


Figure 39:
Shoshonite, Jackson Bay suite; 2.9 km southeast of Eight Mile Point.

The porphyritic andesites (8c) are vesicular, grey-green, fine- to medium-grained, locally pillowed rocks, with a black and white speckled, pitted weathered surface. In contrast with the shoshonites, the andesites contain greenish plagioclase phenocrysts that are stubby, tabular and generally not longer than 4 mm. Plagioclase is heavily altered, containing sericite, chlorite and carbonate aggregates and some muscovite blasts. Black stubby pseudomorphs after mafic phenocrysts (up to 5 mm) show up in hand specimen. Under the microscope, the pseudomorphs are made up of chlorite, light green amphibole, magnetite and carbonate. The porphyritic andesite may contain sporadic quartz phenocrysts. The groundmass consists of chlorite, biotite, quartz, plagioclase, carbonate, opaques, sphene and tourmaline.

The dacites and rhyolites (unit 8d) are grey rocks with a creamy white weathered surface. The rhyolites are aphyric. The dacites are fine grained and locally porphyritic, containing quartz and abundant plagioclase phenocrysts up to 4 mm in size. The rocks comprise plagioclase microphenocrysts and minor internally recrystallized quartz-eyes. Some samples contain yellow-brown clinozoisite pseudomorphs after deformed biotite phenocrysts. The matrix is made up of muscovite, biotite, plagioclase, quartz, chlorite, epidote, apatite, sphene and opaques.

Porphyritic dacite dykes, sills and flows of units 8b and 8c outside Jackson Bay

Dykes, sills and flows that are texturally similar to those of the Jackson Bay suite were occasionally documented within rocks of the Hayes River Group (unit 1)and the Traverse Island sequence (units 8e, 8g, 8h, see below).

Trachytic dacite dykes that show a close textural resemblance to the shoshonites (8b) were documented in three separate locations in sheared basalt and pillowed basalt of the Hayes River Group 0.2 km, 2.4 km and 2.9 km due west of Pisew Island, respectively. The dykes are generally boudinaged and range in width from 8 to 60 cm. The tabular plagioclase phenocrysts (8 mm long) are completely saussuritized and fringed by biotite. The groundmass is quartzofeldspathic and contains epidote. These dykes are unique and unlike any lithology of the Hayes River Group.

A 60 cm wide trachytic dacite dyke was mapped on a small island 2.4 km east of Kawapasik Narrows. A 1.5 metre thick, weakly porphyritic dyke occurs on a reef southwest of Traverse Island. Both dykes cut strata of the Traverse Island sequence.

A 1.5 metre wide pillowed flow of porphyritic andesite (8c) occurs on a small island 1.4 km east-southeast of Kawapisik Narrows. Several massive and pillowed flows of locally porphyritic andesite (8c) occur near eastern Traverse Island. In both locations the flows are intercalated with strata of the Traverse Island sequence.

Breccias and conglomerates (8b3, 8b4, 8c3, 8c4, 8d2, 8d3)

Rocks of units 8b, 8c and 8d occur as flows and intimately associated volcaniclastic and epiclastic breccias. Shoshonite and porphyritic andesite breccias (8b3, 8c3), in particular, are repeatedly interlayered with tuffaceous wacke and mudstone suggesting local reworking by water action. The ambiguity of many of the volcanogenic breccias of Eight Mile Point-Jackson Bay area was also noticed by Barry (1959).

The fragments and matrices of the breccias usually have similar compositions. Breccias containing well defined, but fairly equant fragments, that may be as large as 1 m across, occur intercalated with flows and are interpreted as block lava (Fig. 40). Subrounded and well rounded fragments, however, occur in varying quantities in flows, possibly as a result of auto-brecciation of solidified lava fragments, or perhaps representing pre-existing rubble of similar composition. This process is particularly evident in porphyritic andesite flows, where larger fragments are crumbled and brecciated.

The shoshonite breccias are commonly characterized by isolated, vaguely outlined bodies of porphyritic shoshonite with conspicuous plagioclase phenocrysts that are aligned in a parallel or circular fashion (Fig. 41), enclosed in a randomly oriented porphyritic matrix. Conversely, fragments with randomly oriented phenocrysts were documented in a matrix marked by flow-aligned phenocrysts. The fragments are thought to represent clots of an almost solidified flow that were rolled and stretched during flow.

A peculiar volcanic breccia with dacitic fragments and an andesitic matrix occurs 3.5 km south-southeast of Eight Mile Point. Under the microscope the green, andesitic matrix appears to be riddled with late-tectonic biotite porphyroblasts, but a plagioclase porphyritic nature is still clearly discernable. This compositionally bimodal rock is overlain by pillowed porphyritic andesite. The mixed flow-breccia is interpreted as a porphyritic andesite flow with dacitic rubble.

Pillowed porphyritic andesites are common in the Jackson Bay area and local isolated pillows were documented in a hyaloclastic matrix (Fig. 42). Layers of angular fragments of vesicular porphyritic

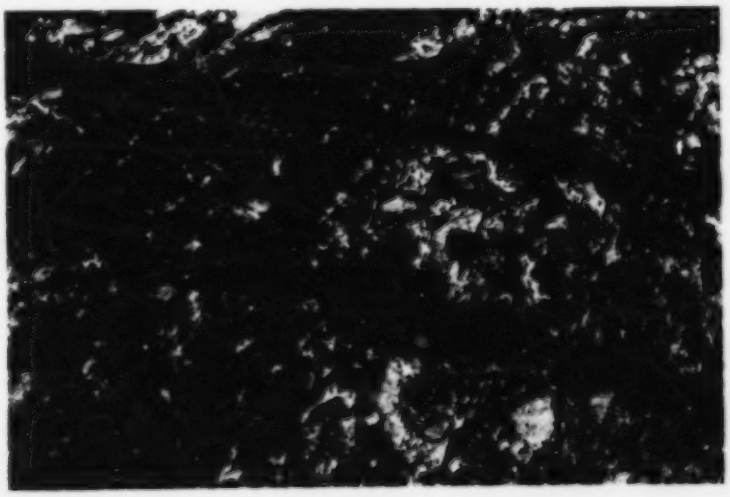


Figure 40:
Porphyritic andesite, block lava, intercalated in massive flows, Jackson Bay suite; 1.2 km east of Jackson Bay.

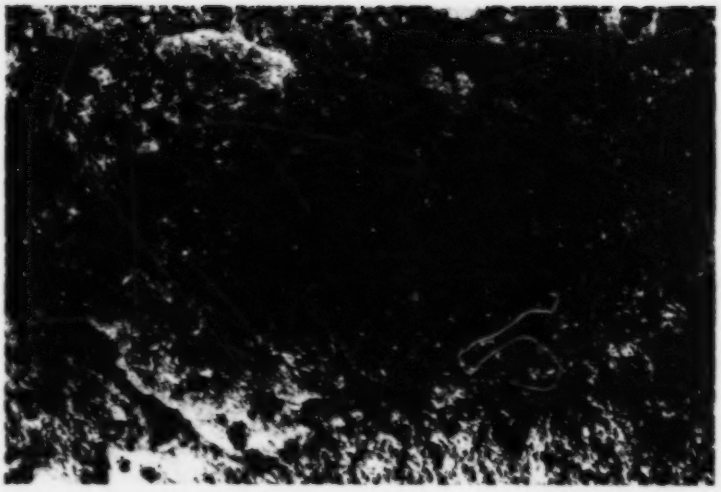


Figure 41:
Shoshonite with inclusion displaying concentrically aligned plagioclase phenocrysts; 2.9 km southeast of Eight Mile Point.

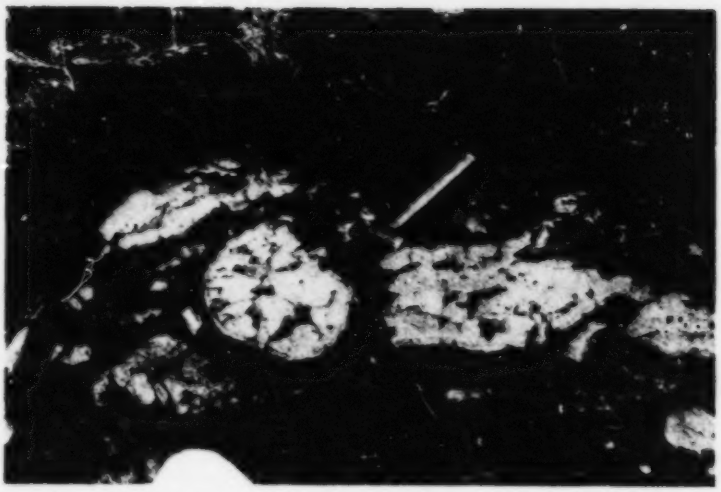


Figure 42:
Isolated pillows of porphyritic andesite in a hyaloclastitic matrix, Jackson Bay suite; 1.0 km south of Eight Mile Point.

andesite may occur intercalated with the pillowed flows and are interpreted as pillow breccia.

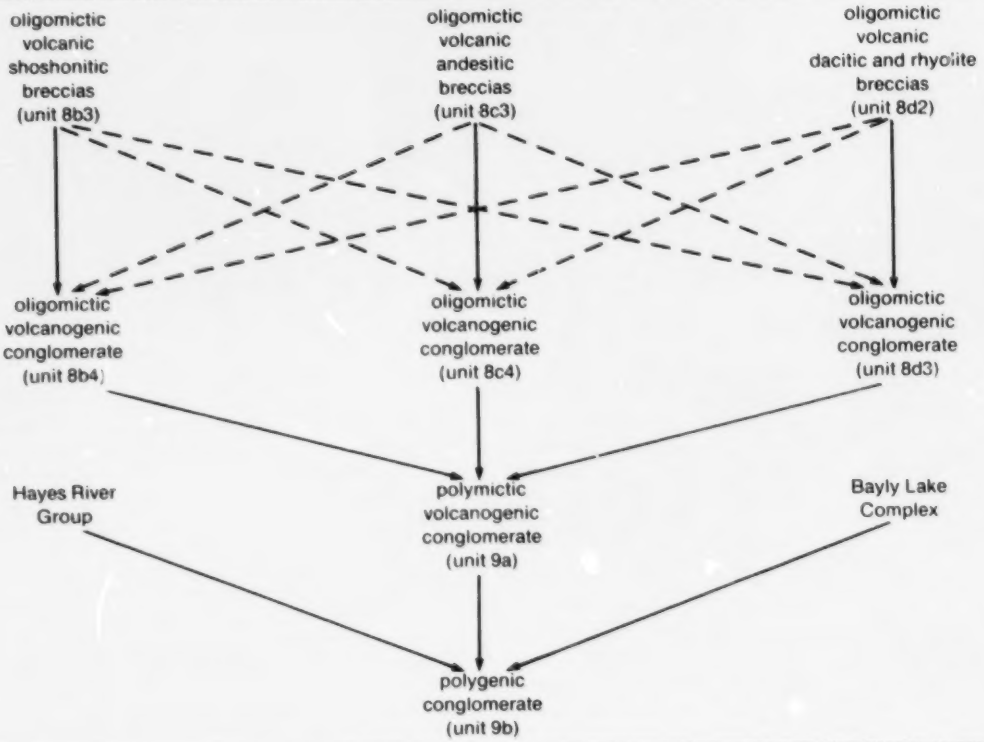
Porphyritic dacite and rhyolite are the major components of pyroclastic deposits (unit 8d2). Most common are lapilli-tuffs. Tuff-breccias and pyroclastic breccias with bombs up to 60 cm across are less abundant. The felsic pyroclastic deposits occur just below the polymictic conglomerates (units 9a and 9b), and appear to be the youngest members of the Jackson Bay suite.

These breccia types form the "end members" of a variety of fragmental pyroclastic and epiclastic deposits that grade lithologically from the volcanic subgroup into polygenetic conglomerates (9b) of the sedimentary subgroup. The transition lithologies include oligomictic volcanic breccias (units 8b3, 8c3, 8d2), oligomictic volcanogenic conglomerates (units 8b4, 8c4, 8d3), and polymictic volcanogenic conglomerates (unit 9a), respectively, with increasing stratigraphic level (Table 6). The total disappearance of angular fragments marks the transition from breccia to conglomerate. The introduction of exotic material such as tonalite and granodiorite debris from the Bayly Lake Complex and volcanogenic detritus from the Hayes River Group distinguishes the polygenetic conglomerates from the volcanogenic conglomerates.

The transition from oligomictic volcanic breccias to polygenetic conglomerates is well documented on the three larger islands that are located 1 - 3 km south-southwest of Eight Mile Point, north of the northeastern corner of Jackson Bay. The oligomictic conglomerates are interlayered with small, graded beds of mafic wacke and siltstone (unit 9g), and interpreted as water-reworked oligomictic volcanic breccia. Although the fragments of the conglomerates are generally smaller than 30 cm, some boulders are 1.5 m large. Evidence for water action is also found in the gradually increasing influx of well-rounded pebbles of varying composition such as rhyolite, porphyritic dacite (and sporadic iron formation) yielding a polymictic volcanogenic conglomerate (unit 9a) that consists entirely of debris from the Jackson Bay suite.

Jackson Bay block lava and absarokite and shoshonite flows could be interpreted to indicate subaerial environment (Ruxton, 1966;

TABLE 6
Provenances of the Oxford Lake Group Conglomerates in Jackson Bay


oligomictic volcanic shoshonitic breccias (unit 8b3)
oligomictic volcanic andesitic breccias (unit 8c3)
oligomictic volcanic dacitic and rhyolite breccias (unit 8d2)
oligomictic volcanogenic conglomerate (unit 8b4)
oligomictic volcanogenic conglomerate (unit 8c4)
oligomictic volcanogenic conglomerate (unit 8d3)
Hayes River Group
polymictic volcanogenic conglomerate (unit 9a)
Bayly Lake Complex
polygenic conglomerate (unit 9b)

Macdonald, 1972), but common occurrences of pillowed flows, conglomerates and water-reworked volcanic breccias suggest that subaqueous conditions prevailed.

Porphyroblastic hornblende schist (8f)

Porphyroblastic hornblende schist is a distinct unit east of Jackson Bay in the axial zone of the Oxford Lake Group. The rocks are "**garbenschiefer**" characterized by sheave-like aggregates of bluish-green amphibole, which developed in foliation planes.

The schists occur in mafic rocks within a northwesterly-trending zone that is on strike with a syntectonic granodiorite (unit 11) occupying the axial zone of the Oxford Lake Group synclinorium between Oxford House and Semple Bay. The metamorphic grade increases towards the granodiorite. The formation of the hornblende schist and the emplacement of the granodiorite were caused by the second Kenoran orogenic event. **Garbenschiefer** textures have not been noted in the Hayes River Group tholeiites that lie adjacent to the granodiorite. The whole-rock composition of the Jackson Bay suite volcanics appears to be the determining factor for the porphyritic growth of bluish-green amphibole. Bluish-green amphibole needles were also formed in a thermal aureole of gabbro (unit 13) intruding mafic greywacke (Fig. 43) derived from Jackson Bay volcanics, in Jackson Bay, 6.5 km west of the main **garbenschiefer** zone.

The bluish-green amphibole ($\gamma\Lambda_C = 15°$, $\delta = 0.020$) form sheaves of conspicuous late-tectonic, sieve-textured prismatic porphyroblasts (up to 3 mm), which enclose opaque inclusion trails that reflect the foliation plane. The sheaves and needles display a polygonal arc-texture, indicating early- to syn-tectonic growth and late-tectonic recrystallization. The amphiboles are commonly riddled with brown pleochroic haloes. The **garbenschiefer** contain varying amounts of late-tectonically recrystallized reddish-brown biotite and pistacite. The matrix consists of aphanitic quartz, carbonate, plagioclase, biotite, muscovite, chlorite and opaques, and rare tourmaline.

Vague outlines of plagioclase phenocrysts indicate an original porphyritic nature for some of the rocks of unit 8f. Other specimens exhibit internally recrystallized globular aggregates, as large as 6 mm, which contain mosaics of quartz, amphibole, plagioclase, microcline and clinozoisite. The aggregates are interpreted as recrystallized vesicles.

Volcaniclastic and epiclastic gravel deposits, tuff, wacke, siltstone and argillite (8e, 8g, 8h) (Traverse Island sequence)

The rocks of the Traverse Island sequence range compositionally from intermediate to felsic and resemble the Jackson Bay suite in that they are porphyritic and form a mixed, alternating succession of volcanic breccias, tuffs, conglomerates and finer grained sediments.

Mafic rocks that are texturally and compositionally comparable to the Jackson Bay suite volcanics occur sporadically as dykes, sills and flows in the Traverse Island sequence.

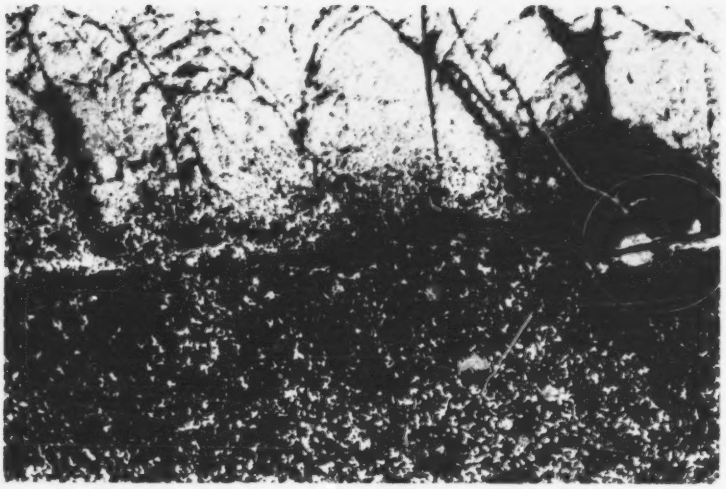


Figure 43:
Contact between mafic greywac :e (unit 10) and gabbro (unit 12). Note the amphibole growth in the greywacke; Jackson Bay.

Volcanic fragmental rocks and conglomerate with porphyritic, felsic to intermediate and minor mafic fragments, minor tuff and wacke (8e)
Predominantly tuff-breccia and pyroclastic breccias (8e1)
Predominantly tuff and lapilli-tuff (8e2)
Conglomerate (8e3)

Tuff breccia (Fig. 44) and lapilli-tuff are the prevailing rock types of this unit. Pyroclastic and conglomeratic deposits form separate successions, but alternating breccia and conglomerate layers less than 1 m thick may also occur. Pyroclastics grade into conglomerates, as documented for the Jackson Bay suite. The pyroclastics are poorly sorted, and comprise angular fragments and 50-80% matrix. The rocks that are transitional between pyroclastics and conglomerates have subrounded fragments, are better sorted, and are commonly intercalated with greywacke. The fragments are derived from volcanic and subvolcanic sources. Well-sorted conglomerates containing well-rounded cobbles, compositionally similar to pyroclastic rocks, are considered to be derived from pyroclastic deposits by water reworking. Conglomerates are also intercalated with greywacke and may contain fragments from foreign sources such as the Hayes River Group and the Bayly Lake Complex.

The sedimentary rocks of this unit are more abundant on southern Carghill Island and east of Carrot Bay. Traverse Island is predominantly underlain by pyroclastic rocks. The deposits with the largest (up to 1 m) fragments were found on western Traverse Island, suggesting the proximity of an eruptive centre.

The composition of the fragments of the pyroclastic deposits is restricted to intermediate and acid volcanic and subvolcanic rocks. Fragments of porphyritic and aphanitic rhyolite, porphyritic amphibole dacite and porphyritic andesite are most abundant. The rhyolite and porphyritic andesite resemble the Jackson Bay suite, but the porphyritic amphibole dacite is unique for this unit. It occurs only as fragments in pyroclastics and conglomerates but not as flows.

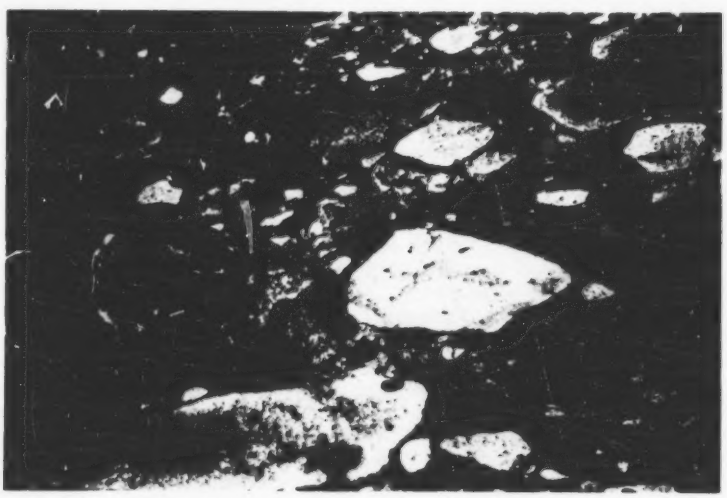


Figure 44:
Tuff-breccia, Traverse Island sequence; western Traverse Island.

The porphyritic amphibole dacite weathers creamy-white and is pock-marked due to weathered-out vesicles. The fresh rock shows a greenish-buff matrix with dark green amphibole phenocrysts about 4 mm long. Plagioclase phenocrysts (up to 3 mm) are locally clotted together. They are strongly albitized and saussuritized and do not stand out on the weathered surface.

The amphibole phenocrysts are in general completely replaced by pseudomorphic aggregates of light green amphibole, chlorite, yellow pistacite, plagioclase, sphene and carbonate. Locally, the mafic pseudomorphs comprise an amphibole core with an inner corona of biotite, and an outer corona of quartz. Vesicles are internally recrystallized into mosaics of quartz, chlorite, epidote, potassium feldspar, carbonate and apatite. The aphanitic matrix is largely made up of plagioclase, brown-green biotite, quartz, sphene, apatite, amphibole, pistacite, and may contain small radial spherulites of yellow pistacite.

The porphyritic andesites have a dark green fresh surface. Dark mafic phenocrysts are distinct on the weathered grey-green surface. Although richer in amphibole, the porphyritic andesites are mineralogically similar to the porphyritic amphibole dacites.

The porphyritic rhyolite fragments weather white and exhibit a creamy white, pink or buff fresh surface. The rhyolite contains feldspar phenocrysts up to 3 mm long and sporadic quartz phenocrysts. In thin section the rock is made up of slightly sericitized, short tabular albite phenocrysts and quartz eyes set in a pilotaxitic matrix of lath-shaped microphenocrysts of plagioclase and sphene, chlorite and epidote.

The polymictic volcanogenic conglomerates of unit 8 are largely comprised of fragments similar to those described above (Fig. 45). The conglomerate beds at southern Carghill Island and northwestern Traverse Island also contain well-rounded fragments of porphyritic tonalite which strongly resembles the porphyritic tonalite of units 4 and 5 of the Lynx Bay area. The tonalite contains equant stubby, dark green amphibole phenocrysts, greenish-yellow plagioclase phenocrysts (about 3 mm across), and blue quartz eyes. A boulder of tonalite gneiss (similar to unit 6) was found in polygenetic conglomerate on northwestern Traverse Island.

Feldspathic greywacke, siltstone, argillite and minor chert (8g)
Mafic tuff and lapilli-tuff (8h)

Pyroclastic deposits and sediments that are generally finer grained than those of unit 8e occur most abundantly on eastern Traverse Island, southeastern Carghill Island and on the islands northeast of Carrot Point.

Lapilli-tuffs are well exposed on central eastern Traverse Island. The rocks contain angular, white weathered fragments (up to 3 cm, Fig. 46) of porphyritic rhyolite, porphyritic amphibole dacite and angular plagioclase phenocrysts, and are intercalated with delicately banded grey-green to white siltstone or fine grained tuff (Fig. 47) that shows graded bedding. They consist of aphanitic biotite, chlorite, clinozoisite, carbonate, opaques and quartzofeldspathic matter. The banding reflects different biotite-clinozoisite ratios.

The northeastern tip of Traverse Island is underlain by a succession of sand-sized feldspathic tuff, and feldspathic and lithic greywacke with sporadic cherty interlayers. The tuff is made up of plagioclase and pilotaxitic rhyolite fragments. The sediments, particularly the lithic greywacke, are more mafic in composition than the tuff, and also contain fragments of hornblende dacite.

Grey-green lithic wacke, characterized by round to oval greenish knots (0.5 to 2.0 cm), occurs in the same succession at northeastern Traverse Island. The detrital fragments consist of plagioclase, porphyritic rhyolite, epidote aggregates, quartz and local potassium feldspar. The smaller plagioclase grains have retained their idiomorphic shapes. The matrix consists of biotite, epidote, plagioclase, quartz, carbonate and sphene. In thin section the knots appear to be circular domains in which the matrix biotite has been replaced by granules of epidote. Carbonate is more abundant in the epidote domains. The clastic texture of the rocks is well preserved inside the epidote domain. The epidote-rich knots were presumably formed during incipient metamorphism. The knots and rocks were mistakenly described as cordierite and "**knotenschiefer**", respectively, by Barry (1960). Similar knotty greywacke was documented by Weber (1971) in the Stormy Lake Formation (southeast Manitoba).

Porphyritic biotite diorite (8j)

A porphyritic biotite diorite sill (8j) documented on an island 1.6 km northeast of Carrot Bay intruded greywacke and argillite (8g). The diorite has a subvolcanic texture and its mineralogical composition is similar to the pyroclastic rocks of unit 8e. Lath-shaped albite phenocrysts are less saussuritized than in the extrusive rocks. Vaguely discernable biotite phenocrysts are completely replaced by clinozoisite, secondary biotite, sphene and quartz. The original amphibole or pyroxene phenocrysts are replaced by secondary biotite, amphibole and sphene. The matrix is composed of biotite, amphibole, epidote, muscovite, sphene, carbonate and apatite.

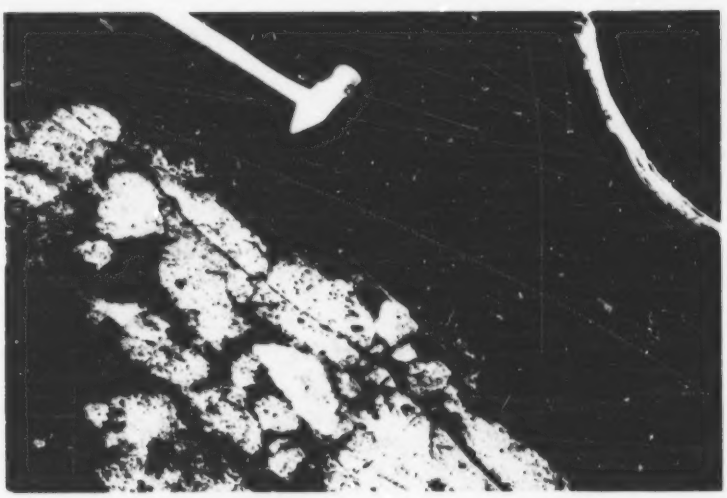


Figure 45:
Polymictic volcanogenic conglomerate, Traverse Island sequence; southern shore of Carghill Island.

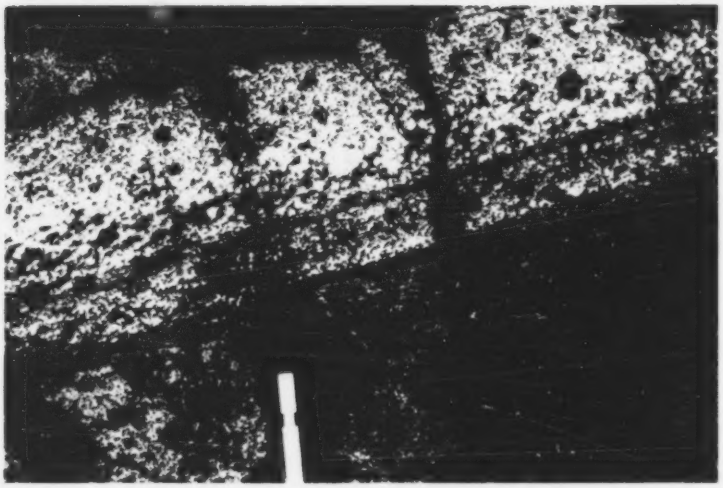


Figure 46.
Tuff and lapilli-tuff, Traverse Island sequence; eastern Traverse Island.

Petrography of the sedimentary subgroup of the Oxford Lake Group

Two major zones of the sedimentary subgroup at Oxford Lake are separated by the volcanic subgroup. The northern zone covers the area between Hyers Point and Semple Bay, and the Hayes River area south of Back Lake. The southern zone covers southeast Oxford Lake, Kisetpiskanak Island and the Laidlaw Creek area.

NORTHEASTERN OXFORD LAKE

The sedimentary subgroup forms a synclinorial belt in this area. The unconformable relationship with the Hayes River Group was described earlier. The base of the sedimentary subgroup is made up of conglomerates (9), which are well exposed at Eight Mile Point, Semple Bay and Hyers Point. Scattered outcrops of conglomerate occur along Hayes River. The central part of the sedimentary subgroup consists of greywacke and minor argillite. The northern extension is intruded by an early to syn-orogenic granodiorite (11). The grade of metamorphism of the sediments increases towards the granodiorite and the axial zone of the Oxford Lake Group.

CENTRAL OXFORD LAKE

Units 9 and 10 underlie a synclinorial sequence in south-central Oxford Lake. Greywacke and conglomerate beds face away, i.e., to the south, from the Jackson Bay suite on the northeastern shore of Jackson Bay. The facing direction is north in the zone extending from Kisetpiskanak Island over Cat Eye Bay to northern Michikinabish Lake. The synclinorium closes on the island west of Kisetpiskanak Island. Conglomerates occur in the lower sections of the sedimentary subgroup.

Thin porphyritic andesite dykes (8c) cut sediments of unit 10 on the largest island in Jackson Bay. The sediments overlie conglomerates (9) that are mainly made up of clasts of the Jackson Bay suite. The presence of dykes is evidence that rocks of the volcanic and sedimentary subgroups are at least partially contemporaneous.

Figure 47: Delicately banded tuff, Traverse Island sequence; eastern Traverse Island.

UNIT 9: METACONGLOMERATE; MINOR META-GREYWACKE

Polymictic volcanogenic conglomerate (9a)

Polygenic conglomerate, minor pebbly greywacke and greywacke (9b)

Detailed analyses of clast-size distribution and composition of the conglomerates were carried out in five locations in northeastern Oxford Lake and two locations in central Oxford Lake (Fig. 48). Because of the small number, the analyses reflect local rather than regional conditions. Point-counts were carried out with a 1 m x 2 m grid with 10 cm spacing. The results of the detailed counts are given in Table 7.

Northeastern Oxford Lake

The polygenetic conglomerate (9b) at Hyers Point is interbedded with greywacke and is at least 250 m thick. The cobbles are rounded and rarely larger than 25 cm. The average size of the ten largest clasts is 10 cm. The detailed count (Fig. 48, Location A) shows that fragments over 8 mm make up 37% of the rock volume. The clasts comprise rusty coloured granodiorite and granite (17 vol.%), aphanitic rhyolite (12 vol.%), basalt (4 vol.%) and greywacke (4 vol.%). The greywacke matrix makes up about 63% of the rock volume.

At Hyers Point the conglomerate beds face away from the Hayes River Group which is exposed at Forestry Point and Back Lake. The contact between the Oxford Lake Group and the Hayes River Group is not exposed. The conglomerate grades abruptly into greywacke towards the west, where pebbles are about 4 cm large and make up about 1% of the rock volume. Sporadic pebble beds of about 30 cm wide occur in the greywacke.

The conglomerate outcrops on Hayes River about 2 km south of Back Lake. The nearest outcrops of south-facing pillowed basalts of the Hayes River Group are 1.5 km to the north. The conglomerate is highly sheared. Immediately towards the south, the conglomerate grades into feldspathic greywacke with granodiorite clasts, locally making up about 15% of the rock volume.

Scattered outcrops of conglomerate and sporadic greywacke that are more deformed and metamorphosed than the conglomerates at Hyers Point occur over the next 8 km downstream along Hayes River. The fragments measure up to 80 cm across and are composed of aphanitic creamy rhyolite, rusty-brown tonalite, quartz-porphyry, porphyry, basalt and iron formation.

The conglomerates near Oxford House are devoid of detritus derived from the Jackson Bay suite, which is a major component of the Eight Mile Point conglomerate. Shoshonite fragments were also found in the conglomerate at Semple Bay.

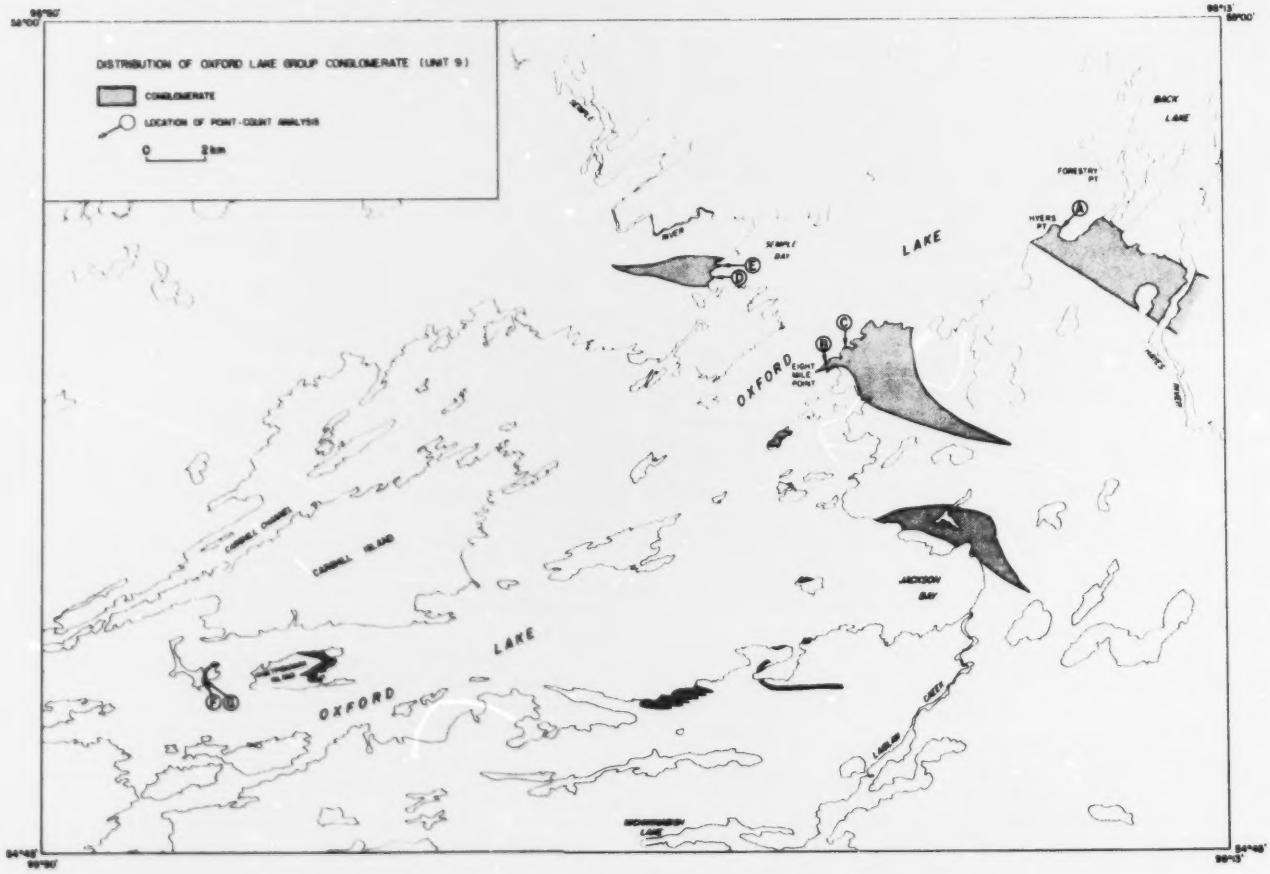


Figure 48: Distribution of Oxford Lake Group conglomerate and location of point-count analyses.

TABLE 7
Statistical Clasts Analysis in Oxford Lake Group Conglomerates (Unit 9)

Locality	A	B	C	D	E	F	G
— average size of 10 largest clasts (cm)	10.1 cm	47.8	39.5	11.6	34.0	21.5	28.7
— vol. % of fragments greater than 8 mm	37%	45	59	25.5	38	35.5	58
— vol. % of clast size (cm) with highest frequency	14.5% 3.2-6.4 cm	15 12.8-25.6	15 6.4-12.8	9 3.2-6.4	12.5 12.8-25.6	11 6.4-12.8	14 6.4-12.8
modal composition (vol. %)							
— matrix and fragments less than 8 mm	63	54	42	74.5	58.5	60	41
— granite + granodiorite	17	15	22	4	3	11	7
— tonalite		7			0.5	5	
— basalt	4	10	5	1.5	22	3	6
— shoshonite + porphyritic andesite		7	10		1		
— rhyolite + dacite	12	5	19.5	6	3	7	36
— mesocratic porphyry + hornblendite		0.5		4	11		
-- feldspar porphyry				5.5	0.5	5	6
— chert + quartz				1.5		6	1
— greywacke	4	1.5	1.5	3.0	0.5	3	3
F/F + M	0.88	0.61	0.73	0.76	0.17	0.92	0.89
V/V + P	0.48	0.49	0.62	0.36	0.63	0.28	0.76

At Eight Mile Point polygenetic conglomerate (9b) forms a layer 2.4 km wide and grades into a polymictic volcanogenic conglomerate (9a) that is transitional between the sedimentary and the volcanic subgroup of the Oxford Lake Group towards the southwest. Towards the east the conglomerate grades abruptly into feldspathic greywacke (10a). The conglomerate at Eight Mile Point varies widely in composition. Shoshonitic and porphyritic andesite boulders (Fig. 49), up to 1.5 m, (derived from the Jackson Bay suite), make up 15% of the volume. Local, up to 1 m, porphyritic tonalite boulders make up about 50% of the rock volume. Fragments of porphyritic dacite (8d), aphanitic rhyolite, porphyritic rhyolite, chert, fine grained plagioclase porphyry and basalt were also documented. The clast:matrix ratio can be as high as 4:1. The tonalite fragments are greyish-green and medium- to coarse-grained. The texture varies from massive to porphyritic. The tonalites and plagioclase porphyry commonly contain disseminated sulphides. Thin section examination indicates that they are hydrothermally altered. Propylitic alteration is most common. One tonalite clast was found to contain rutile, which is characteristic for the hydrothermally altered tonalites, porphyries and volcanics of the Lynx Bay area.

At 500 m northeast of Eight Mile Point (Fig. 48, Location B) fragments over 8 mm make up 46% of the rock volume. The conglomerates comprise clasts of granodiorite, granite and tonalite (22%), basalt (10%), trachytic shoshonite and porphyritic andesite (7%), dacite and rhyolite (5%), and 54 vol.% of pebbly greywacke matrix.

At 1300 m northeast of Eight Mile Point (Fig. 48, Location C) about 58% of the rock volume constitutes fragments over 8 mm. The largest fragment (60 cm) is a shoshonite boulder (Fig. 49). The average size of the ten largest clasts is 39.5 cm. The conglomerate consists primarily of granodiorite and tonalite (22 vol.%), rhyolite and dacite (19.5%), shoshonite (10%) and pebbly greywacke matrix (42%).

The conglomerate extends along strike in a southeasterly direction, flanking the northeastern margin of the Jackson Bay suite. Another shoreline outcrop of conglomerate occurs 2 km southeast of Eight Mile Point. Well rounded clasts, 5 to 25 cm in diameter, are composed of porphyritic tonalite, shoshonite, porphyritic andesite, aphanitic rhyolite and granodiorite. The average clast size is about 10 cm. Sulphide fragments have caused a rusty stain on the outcrop.

The maximum boulder size decreases with increasing stratigraphic height to about 40 cm at 2.4 km northeast of Eight Mile Point (Fig. 50). The uppermost conglomerate beds (with pebbles up to 8 cm) are intercalated with 15 to 40 cm wide greywacke beds (Fig. 51). The fragments are composed of basalt, rhyolite, granodiorite and tonalite, porphyry and greywacke. Detritus derived from the Jackson Bay suite is no longer a major component.

Polygenetic conglomerate (9b) in Semple Bay is on strike with the Eight Mile Point conglomerate. The conglomerate is interbedded with greywacke and is intruded by the Semple River granodiorite (11). The largest boulders (up to 50 cm) consist of granodiorite. Well rounded cobbles of creamy-brown quartz-plagioclase porphyry form an important felsic component. Mafic fragments include aphanitic basalt, and porphyritic and medium grained hornblendite.

A detailed count (Fig. 48, Location D) showed that the average size of the ten largest clasts is 11.6 cm. Only 25.5% of the rock volume is made up of fragments over 8 mm. The conglomerate contains rhyolite (6%), porphyry (5.5%), granodiorite (4%), porphyritic hornblendites and mesocratic porphyry (4%) and pebbly greywacke matrix (74.5%).

The sporadic occurrence of shoshonite fragments in the Semple Bay conglomerate corroborates the view that it is the northern extension of the Eight Mile Point deposit. About 38% of the volume of the Semple Bay conglomerate in location E (Fig. 48) is made up of

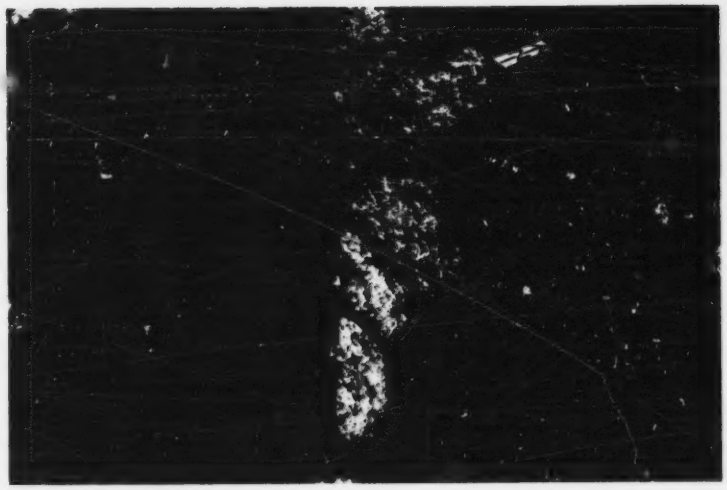


Figure 49:
Shoshonite boulders in polygenic conglomerate (unit 9b); 0.9 km east of Eight Mile Point.

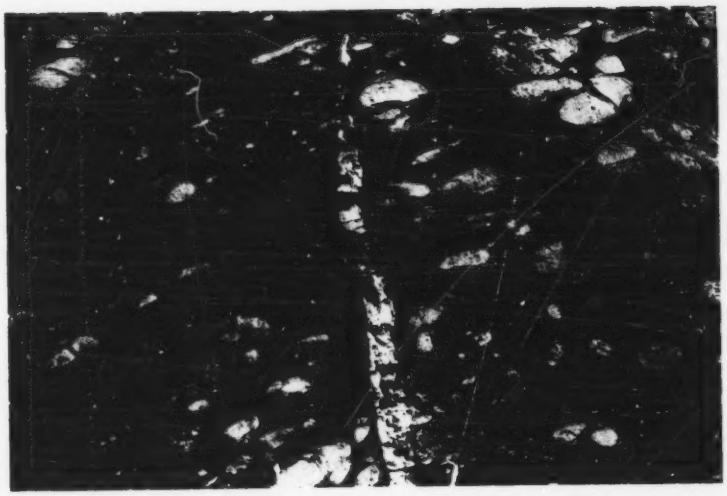


Figure 50:
Polygenic conglomerate (unit 9b); 2.9 km northeast of Eight Mile Point.

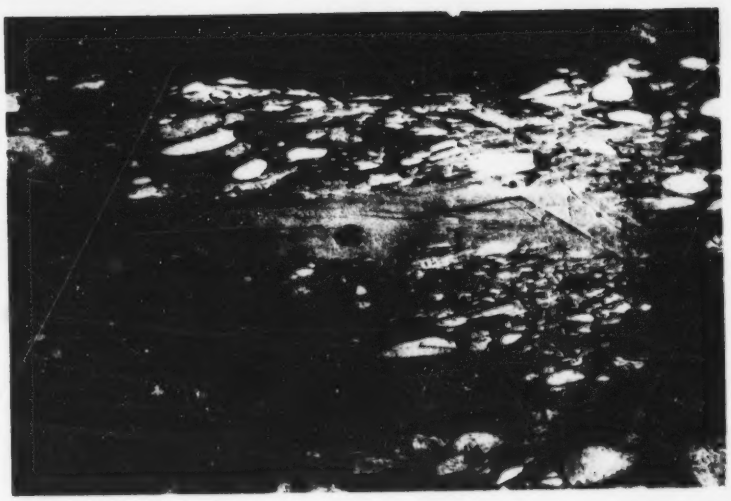


Figure 51:
Polygenic conglomerate (unit 9b) interbedded with greywacke; 2.9 km northeast of Eight Mile Point.

fragments over 8 mm. The conglomerate consists of basalt (22%), mesocratic porphyry (11%), shoshonite (1%), rhyolite (3%), granodiorite and tonalite (3.5%) and pebbly greywacke matrix (58.5%).

Some scattered inland outcrops of the Semple Bay conglomerate have a higher content of well rounded felsic pebbles of quartz-eye rhyolite and feldspar than the rather mafic conglomerates at the shoreline.

South-central Oxford Lake

Polygenetic conglomerate layers, up to 150 m thick, occupy the lower stratigraphic levels of the sedimentary subgroup at south-central Oxford Lake. Conspicuous fragments derived from the Jackson Bay suite occur in the conglomerate in northeastern Jackson Bay and along the north shore of the largest island in Jackson Bay, 7 km south of Eight Mile Point. The conglomerate clasts at the southern shore of Oxford Lake comprise mainly Hayes River Group and Bayly Lake Complex rocks, such as rusty-brown granodiorite, quartz-eye porphyritic tonalite, massive tonalite, aphanitic rhyolite and basalt (Fig. 52).

The clasts in the conglomerate near Kisetpiskanak Island consist mainly of tonalite and dark green porphyritic dacite, yellowish-green amphibole dacite, aphanitic basalt and buff porphyritic rhyolite derived from the Hayes River Group and the Traverse Island sequence. Tonalite fragments, however, are most conspicuous as they have retained oval and egg-like shapes among the sheared and stretched mafic volcanic clasts, and their white-weathered surfaces, often riddled with rusty specks, contrast with the darker volcanic fragments. The tonalitic cobbles are locally rusty brown due to the breakdown of disseminated sulphides. The tonalites are medium- to coarse-grained and vary from porphyritic to equigranular non-porphyritic. The tonalite cobbles exhibit hydrothermal propylitic alteration features such as described for the porphyritic tonalites of the Lynx Bay region. Quartz is abundant in the matrix but does not form phenocrysts as in the porphyritic quartz-eye tonalite of the Lynx Bay area. The mineralogical composition of the tonalite fragments resembles that of the tonalite-granodiorite body (unit 7) at Cat Eye Bay.

The composition and size of clasts were analyzed in locations F and G on the southeastern shore of the Island west of Kisetpiskanak Island, directly above and 15 m above the contact with the Hayes River Group, respectively (Fig. 48). The average size of the ten largest clasts is 21.5 cm directly above the contact. In Location G the average size is 28.7 cm. The pebbly matrix makes up 60 vol.% and 41 vol.% of the conglomerate in Locations F and G, respectively.

Conspicuous chert and quartz pebbles are present (6 vol.%) in the basal part of the conglomerate (Location F; Fig. 53). Granodiorite, granite, tonalite and feldspar porphyry make up 21 vol.%. Rhyolite and basalt represent 7 vol.% and 3 vol.%, respectively . The volcanic com-

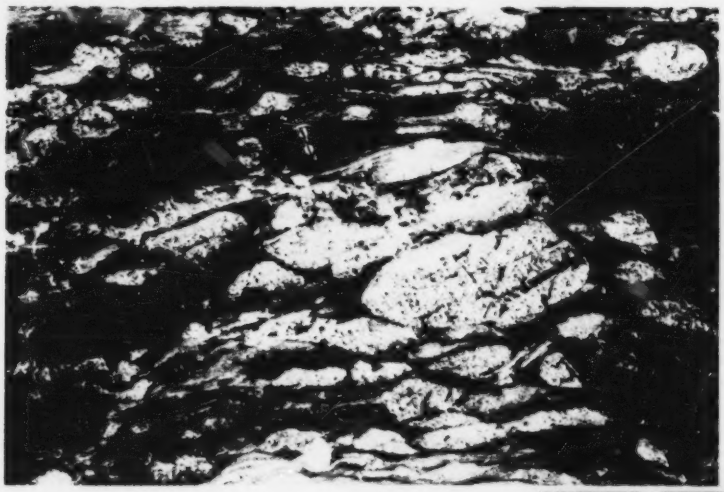


Figure 52:
Polygenic conglomerate (unit 9b); 2.2 km northeast of Cat Eye Bay. Note preponderance of tonalitic boulders.

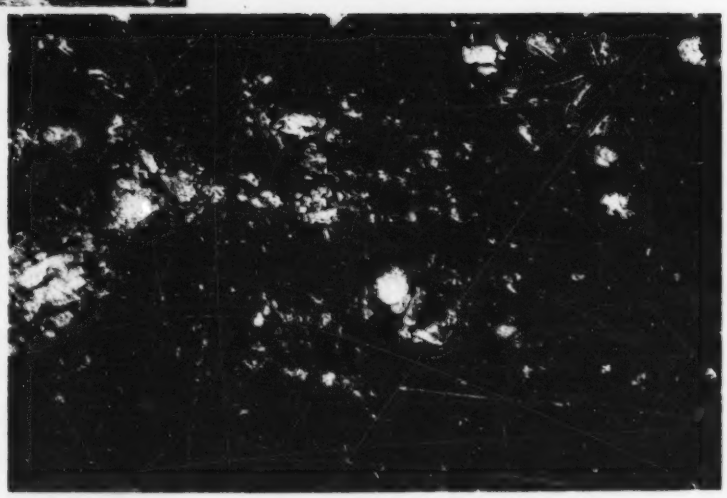


Figure 53:
Basal polygenic conglomerate (unit 9b) resting upon featureless Hayes River Group basalt at southern Thomsen Island. Pencil at contact.

ponent is much higher in Location G, where rhyolite and basalt respectively make up 36% and 6% of the conglomerate volume. Granodiorite and feldspar porphyry represent 13% of the rock volume.

The conglomerate northeast of Cat Eye Bay contains predominantly felsic plutonic material (Fig. 52). Aphanitic rhyolite, quartz and felsic fragments are also present. Boulders rarely exceed 1 m and are generally not larger than 35 cm. The conglomerate contains numerous hydrothermally altered and weakly mineralized tonalitic cobbles of various textural types. The mineralogical composition of the tonalite cobbles resembles that of the Cat Eye Bay tonalite (unit 7). Some potassium feldspar-free cobbles are porphyritic tonalite with blue quartz eyes and resemble the Lynx Bay porphyritic tonalite.

Concluding remarks

The detailed analyses suggest that felsic rocks such as rhyolite, feldspar porphyry and particularly tonalite and granodiorite make up most of the identifiable fragments of the conglomerates. Only the Semple Bay conglomerate has a locally high content (22 vol.%) of basalt fragments. The bulk composition of the conglomerates does not reflect the overall composition of the source areas; rhyolite, for example, is a minor component of the Hayes River Group. The relative abundance of rhyolite in conglomerates is a common feature according to Pettijohn (1975) as felsic materials have a greater survival ability and gravel-forming capability than mafic rocks. This is indirectly illustrated by Figure 54. Plots for conglomerate point counts from the same locality are connected by tie-lines. Figure 54-A suggests that the average size of the ten largest fragments decreases with decreasing amount of recognizable mafic mineral. In other words, where the conglomerates are predominantly made up of felsic fragments, the deposits are likely to have smaller fragments as compared to deposits with a mixed mafic-felsic composition. There is no clear relationship between the F/F + M value and the amount of pebbly matrix (Fig. 54-B). Figure 54-C indicates a positive relationship between the amount of recognizable basaltic material and the average size of the ten largest clasts. Figure 54-D suggests that the pebbly matrix component increases with decreasing amounts of recognizable volcanic material. Thus, progressive abrasion of the conglomerate fragments resulted in a reduction of the amount of recognizable volcanic, particularly mafic, material which most likely makes up the matrix.

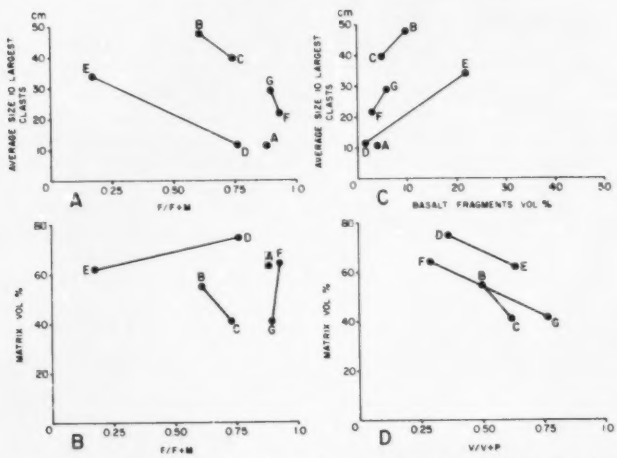


Figure 54: Modal compositions and fragment sizes of Oxford Lake Group conglomerates. See Figure 48 and Table 7. F: felsic plutonic and volcanic rocks, chert and quartz; M: mafic volcanic rocks and porphyrites. V: volcanic rocks; P: plutonic and porphyritic rocks.

UNIT 10: METAGREYWACKE, META-ARENITE; MINOR METAPELITE, AMPHIBOLITE AND PARAGNEISS

The finer grained sediments of the sedimentary subgroup of the Oxford Lake Group are well exposed along the shore between Jackson Bay and Cat Eye Bay and underlie islands in Jackson Bay and scattered outcrops along Laidlaw Creek. Unit 10 extends westwards cropping out as reefs and islands north of Cat Eye Bay and near Kisetpiskanak Island. A 6 km wide zone of fine grained metasediments west of Oxford House is intruded by a granodiorite pluton (11). The sediments are gneissic in this section and in the area just west of the mouth of Laidlaw Creek.

Feldspathic greywacke; minor pebbly greywacke (10a)
Arenite, arkosic wacke (10b)
Pelite and calc-silicate rock (10c)

Unit 10 is mainly composed of feldspathic, creamy grey to greyish-green greywacke with sporadic pebbly layers north and west of Cat Eye Bay. In thin section it appears that feldspar detritus prevails over quartz, lithic fragments and rare potassium feldspar. Plagioclase fragments, typically albite, derived from felsic volcanic sources, are commonly angular and show subhedral outlines. Plutonic plagioclase tends to be more rounded. The lithic fragments also suggest volcanic and sub-volcanic sources like basalt, plagioclase porphyry and porphyritic amphibole dacite (8e). Other detrital minerals are amphibole and epidote, and minor sphene, apatite, tourmaline, zircon and sporadic rutile. The matrix is commonly recrystallized. It is quartzofeldspathic and contains biotite, chlorite, epidote and minor sericite, amphibole and opaques.

The southern part of Kisetpiskanak Island is underlain by dense, dark sediments with a slaty appearance.

Quartzofeldspathic sediments, such as feldspathic greywacke, arkosic wacke and arkosic arenite underlie the southern shore of Oxford Lake between Cat Eye Bay and Laidlaw Creek. Feldspathic greywacke and arkosic wacke occur along Laidlaw Creek. The prevailing detrital minerals are subangular to well-rounded quartz and polysynthetically twinned albite. Other detrital minerals include amphibole, epidote, microcline, zircon, sphene and apatite. The matrix and fine grained lithic fragments are generally completely recrystallized. Only rare basaltic fragments were recognized. The matrices are made up of biotite, muscovite, sericite, chlorite, quartz, plagioclase, epidote and opaques. The feldspathic sediments are commonly intercalated with pelitic, locally pyritiferous beds between Laidlaw Creek and the large bay east of Pakitahokansik. Here the Oxford Lake Group appears to change lithologically from conglomerate, overlain by arenites and greywackes towards rocks of pelitic composition, with increasing stratigraphic height. The lithological change may also reflect a lateral facies change as this area adjoins the mafic sediments that underlie Jackson Bay.

The sediments that flank the Jackson Bay suite are dark, lustrous, biotite- and amphibole-rich, massive to laminated wackes and mudstones. The rocks are largely recrystallized; brown biotite and needles of light green amphibole overgrew the primary clastic texture at random. Lithic fragments of porphyritic and trachytic volcanic material are recognizable in thin section. The matrix contains biotite, amphibole, quartzofeldspathic matter, apatite, opaques and rare potassium feldspar. The mafic sediments are locally interlayered with calc-silicate bands (typically less than 10 cm wide) composed of colourless amphibole, clinozoisite, quartz, chlorite, carbonate and white mica.

Slump and flame structures are common in sedimentary rocks (Fig. 55) from the northern part of Jackson Bay. The dearth of cross-

Figure 55:
Slump and flame structure in mafic wacke (unit 10); Jackson Bay.

bedded sediments indicates a quiet despositional environment. Calc-silicate layers are considered to represent calcareous mud. Limy ovoid pebble-like inclusions, generally not larger than 2 cm in length, may form "pebbly" layers (Fig. 56) intercalated with mudstone and calc-silicate bodies with light-coloured limy haloes (Fig. 57). The presence of concretion-like inclusions, the regular distribition and the locally vague boundaries of the "pebbles" seem to suggest a diagenetic or early metamorphic origin rather than interformational redeposition.

In Jackson Bay the mafic sediments have been intruded by a large diabase (12) which was traced from west of Laidlaw Creek to southeastern Carghill Island. The dyke outcrops on several smaller islands and reefs in south-central Oxford Lake. Contact metamorphism caused random blastesis of bluish-green amphibole in the adjacent sediments. The recrystallized matrix of the hornfels consists of biotite, amphibole, plagioclase, quartz, epidote, chlorite and opaques.

The primary textures of the fine grained sediments of northeastern Oxford Lake were generally erased by upper greenschist facies to lower amphibolite facies metamorphism. Clastic textures are still preserved in feldspathic greywackes and arkosic arenites, associated with conglomerates at Hyers Point. Plagioclase fragments are subround and polysynthetically twinned and probably derived from a plutonic source. Feldspathic greywacke with lath-shaped, rectangular volcanic plagioclase was documented east of the Eight Mile Point conglomerates. The matrices of the feldspathic sediments are recrystallized and are composed of quartz, plagioclase, biotite and epidote, chlorite, carbonate and opaques.

Amphibolite (10d)
Amphibole-biotite gneiss (10e)
Garnet-, andalusite-, and staurolite-bearing gneisses (10f)

The metasediments west of Laidlaw Creek have a gneissic texture. Upper greenschist to lower amphibolite facies metamorphism caused growth of biotite and local porphyroblastic prismatic amphibole. Amphibole-biotite gneisses, amphibole gneisses and biotite gneisses were also documented in northeastern Oxford Lake. Biotite, syn- to post-tectonic, faint green to bluish-green amphibole ($\gamma \wedge c = 19°$, $\delta = 0.039$) and epidote form a stable assemblage. Chlorite may be part of the assemblage in areas of lower metamorphic grade. Matrix minerals are plagioclase, quartz, rare potassium feldspar, epidote, sphene, tourmaline, opaques and chlorite.

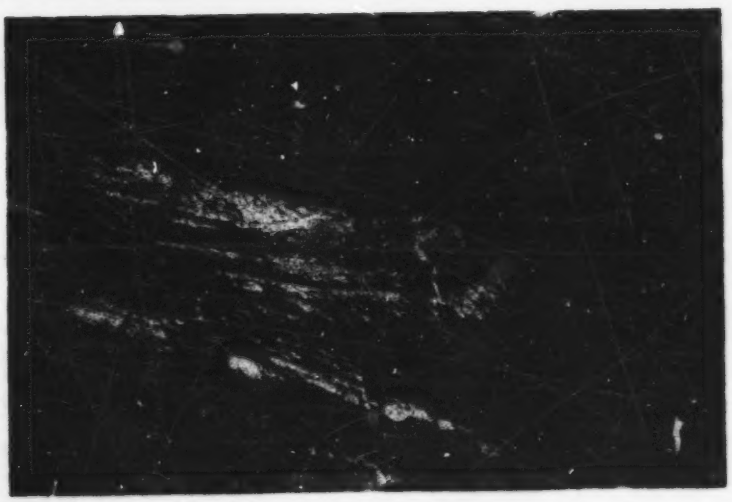


Figure 56:
Intercalated calc-silicate layers and mudstone (unit 10), Jackson Bay. Note the "pebbly" appearance of the calc-silicate layers and the concretion-like inclusion in the lower right-hand corner. See text.

Figure 57:
Concretion-like zoned calc-silicate nodules in mafic greywacke; Jackson Bay.

Garnet-, andalusite- and staurolite-bearing gneisses occur in a narrow amphibolite facies zone that extends from the central Hayes River, and the area west of Forestry Point, towards Stubbs Lake.

A garnet-biotite gneiss was documented on Hayes River, 10 km south of Back Lake. The pinkish-red sieve-textured garnet porphyroblasts overgrew a folded biotite-quartz fabric. The garnet predates a younger biotite- chlorite-amphibole assemblage.

Two isolated outcrops of partially retrograded amphibolite facies sediments occur about 3 km west of Forestry Point. Chlorite pseudomorphs after garnet were documented in a chlorite-biotite gneiss in the western outcrop. The eastern exposure shows an isoclinally folded metasediment in which the original compositional layering is reflected by several different metamorphic assemblages including staurolite-andalusite-biotite schist, garnet-biotite gneiss, garnet-andalusite-biotite gneiss and diopside-cummingtonite-hornblende-garnet gneiss. The significance of these mineralogical assemblages will be discussed under Metamorphism.

PROVENANCE OF THE METASEDIMENTS

The mineralogical and modal compositions of the fine grained metasediments reflect the composition of the older rocks. This relationship is well illustrated by sediments of south-central Oxford Lake (Fig. 58). Rare detrital potassium feldspar occurs in the lower stratigraphic levels only and it is thought to have been derived from the potassium feldspar-bearing Cat Eye Bay tonalite-granodiorite body. Reddish pleochroic sphene and rutile in the fine grained sediments are restricted to the southern part of the sedimentary subgroup. Reddish pleochroic sphene is characteristic for the tonalitic rocks of units 4 and 7, and rutile only occurs in hydrothermally altered volcanic and subvolcanic rocks of unit 5. The distribution of these typical accessories may well indicate a tonalitic provenance for the sediments that occupy the southern limb of the synclinorial structure of the Oxford Lake Group. The rutile-rich matrix of the basal conglomerate west of Kisetpiskanak Island (Location F, Fig. 48), contains more rutile than the sediments higher up in this stratigraphic succession. Accumulations of needles and grains of rutile accentuate the primary layering. Reddish sphene is not present in the matrix of this conglomerate. On the other hand, reddish sphene is a common detrital accessory in sediments higher up in the stratigraphy of the sedimentary subgroup. The vertical distribution of both titanium minerals in the sediments may reflect an earlier erosion of the high-level Lynx Bay type volcanics (unit 5) and a subsequent unroofing of the deeper-seated porphyritic and igneous rocks of units 4 and 7.

The wackes and mudstones flanking the Jackson Bay suite are considerably more mafic in composition than sediments further west. Amphibole, chlorite and clinozoisite prevail over quartz and feldspar, and biotite is typically abundant in the Jackson Bay suite-derived sediments. The Jackson Bay sediments are devoid of reddish sphene, rutile and potassium feldspar.

The modal compositions of the fine grained sediments and the adjoining older rocks are compared in Figure 59 showing the ratio biotite/quartz, feldspar and muscovite/mafic and calcium-rich minerals (amphibole, epidote, chlorite, oxides and sphene).

Thin sections of 13 fine grained sediments from south-central Oxford Lake were point-counted (Fig. 59). The felsic sediments include arkosic wackes, arkoses and arenites. The intermediate group represents arkosic wackes and feldspathic greywackes. The mafic group includes wackes, mudstones and calc-silicate rocks. The compositions of 29 other samples (Fig. 58) of fine grained sediment were visually estimated using the 13 point-counted samples as standards.

The dearth of mafic minerals in the samples from the area between Laidlaw Creek and Cat Eye Bay confirms the conclusions made previously that the sediments are most likely derived from felsic plutonic sources.

Jackson Bay sediments contain over 50 vol.% of varying amounts of biotite and mafic phases. The sediments are classified as mafic, intermediate and pelitic.

The individual groups plotted in Figure 59 display trends of "biotite-enrichment", which most likely reflect a selective sedimentary process. It is assumed, therefore, that the provenances of the individual groups of plots are more accurately reflected by the plots near the base of the diagram.

Samples from Kisetpiskanak Island, west of Cat Eye Bay, plot in the intermediate field and are most likely derived from the Hayes River Group and the Traverse Island sequence of the Oxford Lake Group.

The sediments from the area north and northwest of Cat Eye Bay were probably derived from a mixed source. The provenance may well have been the Cat Eye Bay area, where the Hayes River Group has been intruded by various tonalitic phases of the Bayly Lake Complex.

The compositional variety and distribution of compositions of the sediments in northeastern Oxford Lake is less reflective of specific provenances. Felsic sediments were documented in the Hayes River area south of Back Lake. Intermediate sediments prevail near Eight Mile Point and Semple Bay. Reddish sphene may sporadically occur as a detrital phase. Accessory feldspar was more frequently documented and is not restricted to certain areas, as in south-central

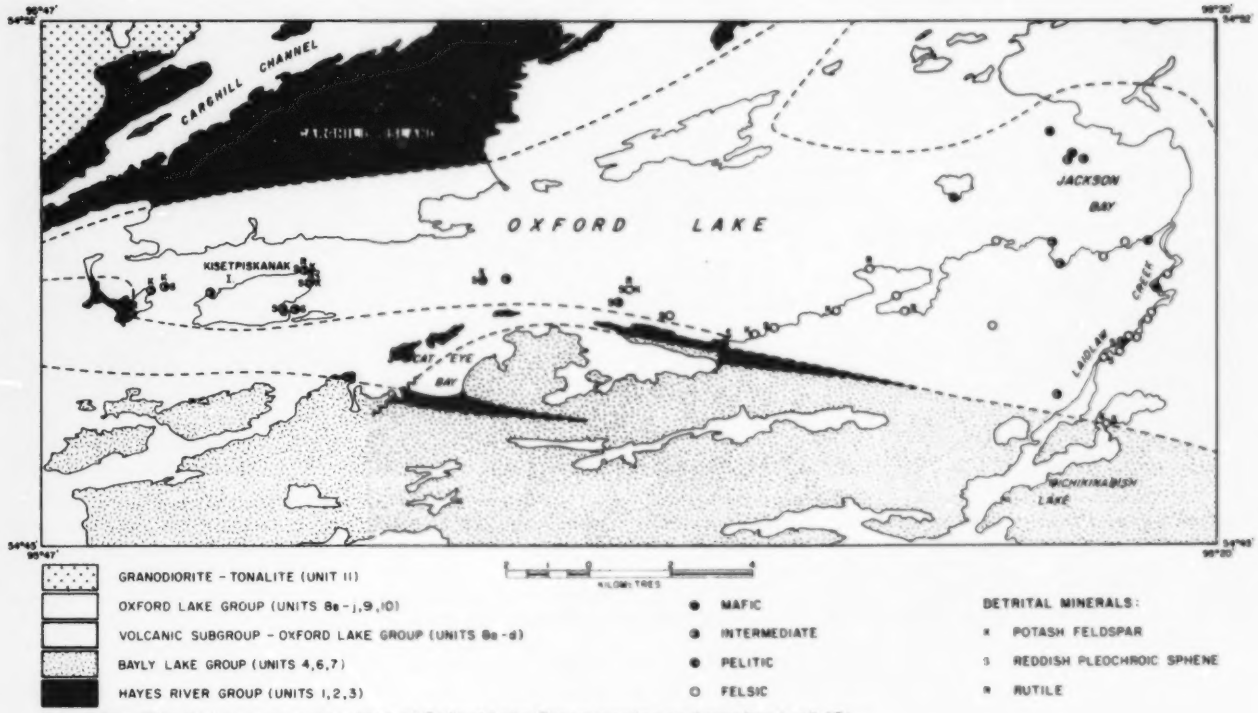


Figure 58: Distribution and composition of Oxford Lake Group wackes and arenites (unit 10).

Oxford Lake. Rutile has not been found in the sediments of northeastern Oxford Lake, although it occurs in hydrothermally altered tonalite cobbles in the Eight Mile Point conglomerate.

BASIN HISTORY

Some general conclusions may be drawn from the distribution of primary sedimentary structures preserved in most of the Oxford Lake Group rocks, with the exception of those sediments in the Carrot Point and High Rock Island area.

Crossbedding and rip-up structures were commonly noticed in the sediments surrounding Jackson Bay and as far west as the largest island in the bay entrance, indicating a high-energy depositional environment. The pelitic and marly sediments in central and southeastern Jackson Bay, however, point to quieter environments, perhaps mudflats with intervening channels in which currents and wave action were sufficiently strong to generate cross-bedding.

Crossbedding, flame and rip-up structures, but also minor graded bedding were documented in the sediments that underlie the south shore of Oxford Lake west of Jackson Bay. Similar features were recorded in the rocks at Traverse Island and southern Carghill Island that are associated with the pyroclastic deposits of the Traverse Island sequence.

Graded bedding was noticed in the adjoining zone directly to the south, that underlies Kisetpiskanak Island, the sediments bordering Cat Eye Bay and the rocks along the Laidlaw Creek. The overall distribution of sedimentary structures in the Oxford Lake Group synclinorium of southern Oxford Lake suggests that the depth of the Oxford Lake Group basin increased towards the south and southwest, away from the volcanic edifice of the volcanic subgroup, south of Eight Mile Point.

The sequence of Oxford Lake Group greywacke and arenite between Eight Mile Point and Forestry Point are thought to have been

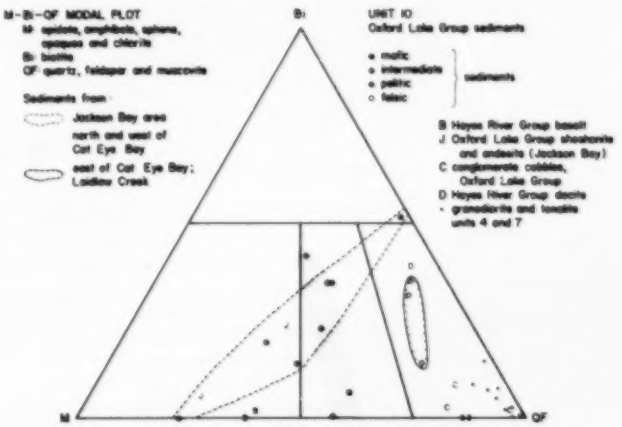

M-Bi-QF MODAL PLOT
M: epidote, amphibole, sphene, opaques and chlorite
Bi: biotite
QF: quartz, feldspar and muscovite
Sediments from:
Jackson Bay area north and west of Cat Eye Bay
east of Cat Eye Bay; Laidlaw Creek
UNIT 10
Oxford Lake Group sediments
mafic
intermediate
pelitic
felsic
sediments
B Hayes River Group basalt
J Oxford Lake Group shoshonite and andesite (Jackson Bay)
C conglomerate cobbles, Oxford Lake Group
D Hayes River Group dacite - granodiorite and tonalite units 4 and 7
M
QF

Figure 59: Mafic minerals versus biotite versus quartz-feldspar modal plot of Oxford Lake Group sediments (unit 10).

deposited beyond wave action, since only graded bedding was observed. The large accumulations of Oxford Lake Group conglomerate in this area and the distribution of sedimentary features suggest that the deeper part of the Oxford Lake Group depositional basin occurred northeast of the Oxford Lake volcanic subgroup. Similar but much less extensive conglomerate deposits, and indications of shallow-water conditions, prevail south and west of the Oxford Lake volcanic subgroup. The relatively deeper section of the Oxford Lake Group basin east of Eight Mile Point was bounded, and possibly also underlain, by rocks of the volcanic subgroup south of Eight Mile Point and in southern Knee Lake (Gilbert, in prep.).

INTRUSIVE ROCKS (UNITS 11, 12, 13)

Rocks of units 11, 12, 13 intrude the metasediments of the Oxford Lake Group. The Semple River metagranodiorite (11) and the metagabbro (12) have been deformed during the second phase of the Kenoran orogeny. The post-Kenoran gabbros and diabases of the Molson dyke swarm (13) are the youngest rocks in the area.

UNIT 11: METAGRANODIORITE

Granodiorite (Semple River granodiorite), granite (11a)
Pegmatite (11b)
Feldspar porphyry (11c)
Aplite (11d)

The Semple River granodiorite pluton (11a) covers most of the inland area north of Oxford Lake. The abundance of pegmatites (11b) and aplites (11d) varies. Contacts with the older tonalites (units 4 and 6) are ill defined in the western Semple River area, due to sparse outcrop and limited lithological contrast.

Contact relationships with the Hayes River Group were documented in Kwaykwaychi Bay where numerous porphyry dykes (11c) cut the porphyritic basalt of unit 1c. Another intrusive contact is located 6 km east of the eastern Semple River inlet in Semple Lake (Fig. 60), where angular amphibolitized fragments (unit 1h) are engulfed in porphyritic quartz-feldspar granodiorite. Feldspar porphyry dykes (11c) cut plagiophyric dolerites (1d) 5.5 km south of the previous location.

Contact relationships with the Oxford Lake Group are well exposed in Semple Bay and on some islands halfway between Semple Bay and Hyers Point. The granodiorite contains numerous metasedimentary rafts and in the Oxford Lake Group metasediments are commonly cut by feldspar porphyry dykes.

Another occurrence of this unit is located 3.5 km south of Back Lake. The nearby exposed greywackes are granitized.

Granite and granodiorite of unit 11a have extensively intruded the migmatitic gneiss terrain of units 4, 6 and 7 in the Windy Lake and Max Lake region. The rocks of unit 11 characteristically truncate the foliation and gneissic layering of the older migmatite complex.

In contrast to the plutonic rocks of units 4 and 6, which are generally conformable to the Hayes River Group, rocks of unit 11 truncate the large-scale structure of the Hayes River Group. However, they intrude the Oxford Lake Group quasi-conformably. The Semple River granodiorite, e.g., is emplaced in the central zone of the synclinorial Oxford Lake Group between Eight Mile Point and Oxford House. The granodiorite is early- to syn-orogenic with respect to the second Kenoran orogenic event; it is strongly foliated and metamorphosed in the central zone of the synclinorium. It is suggested that the formation of the Oxford Lake Group, the emplacement of unit 11 and subsequent deformation and metamorphism, were governed by an orogenic event that involved the Hayes River Group and the pre-tectonic and late-tectonic plutonic rocks of units 4 and 7, respectively.

Most modal analyses of unit 11 plot in the granodiorite field (Fig. 61). The compositional fields of the older tonalites (4) and tonalites, granodiorites and granites of unit 7 are shown for comparison. The Semple River granodiorite defines a trend which is intermediate compared to those of the older units. The time of emplacement relative to the orogenic cycle is reflected by the compositional change from tonalite through granodiorite to granite, regardless of the associated orogenic event. The older tonalites (4) are pre-tectonic rocks. The younger granodiorites (11) are emplaced early or during the second orogenic cycle. The older mainly granodioritic and granitic plutons of unit 7 were intruded during a late stage of the first orogenic event.

PETROGRAPHY

The Semple River granodiorite is a grey to greyish pink, fine- to medium-grained, commonly massive rock. The granodiorite has a weakly porphyritic texture with plagioclase phenocrysts and 'quartz-eyes'.

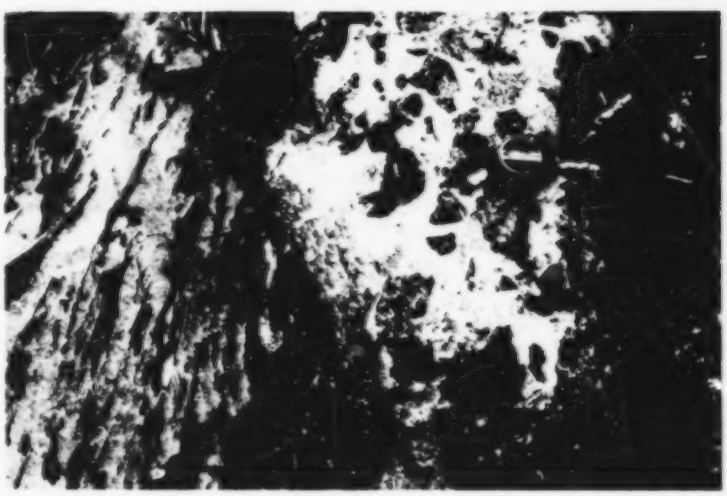


Figure 60:
Intrusive contact between Hayes River Group basalt (unit 1h) and Semple River granodiorite (unit 11); northern Wapaskosowakow Lake.

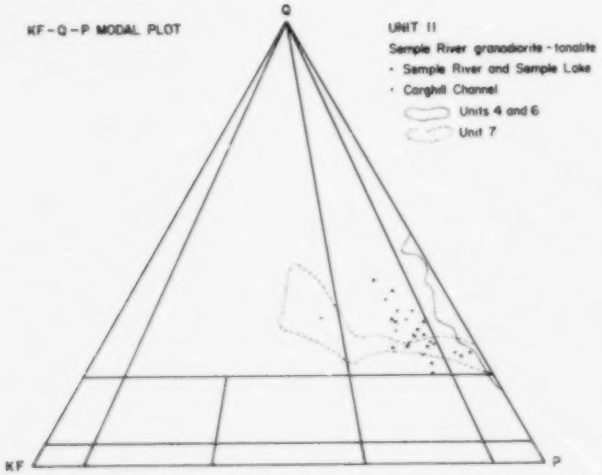


Figure 61: Potassium feldspar-quartz-plagioclase modal plot for the Semple River granodiorite.

The feldspar porphyry dykes have a pink-brown fresh surface. Weathered outcrops are creamy white. Medium grained plagioclase phenocrysts, up to 3 mm, are set in an aphanitic groundmass.

The western part of the granodiorite body is weakly foliated. The rocks east of Semple Bay and Eight Mile Point are strongly foliated and their texture approaches a gneissic fabric on islands in northeastern Oxford Lake.

The rocks of unit 11 are mineralogically similar to granodiorites and granites of unit 7. Plagioclase phenocrysts show a conspicuous igneous zonation and saussuritized cores. The zonation is very pronounced in dykes where plagioclase phenocrysts show rims with an anorthite content 9-18 per cent lower than the cores (30%).

Quartz occurs interstitially and in domains which may represent recrystallized 'quartz-eyes'.

The original mafic phases are completely replaced by biotite, epidote and sporadic chlorite. Muscovite commonly forms cauliflower-like blasts in plagioclase. Sphene, ilmenite, leucoxene, tourmaline and apatite are accessories.

UNIT 12: METAGABBRO

Metagabbro dykes of this unit were mapped in southern Oxford Lake, near Carrot Point and between southeast Carghill Island and the Laidlaw Creek outlet. Several reefs and smaller islands that are aligned in an east-trending zone in southeastern Oxford Lake are underlain by metagabbro, indicating the presence of a large dyke or dyke system with a strike length of at least 18 km and a width of at least 400 m. The smaller dykes have irregular outlines and are locally deformed, in contrast to the straight-walled undeformed diabases of unit 13.

Intrusive relationships with the Oxford Lake Group metasediments (unit 10) have been recorded on southeastern Carghill Island, eastern Traverse Island, the southern tip of the two largest islands in Jackson Bay and 1.5 km west of the Laidlaw Creek outlet. Metagreywacke xenoliths were found in the margin of the locally chilled metagabbro. Contact metamorphism of the Oxford Lake Group sediments was noticed in Jackson Bay where a 5 cm wide zone with random growth of amphibole in the metagreywacke borders the gabbro interface.

PETROGRAPHY

The metagabbro is generally fine- to medium-grained but amphibole crystals may be up to 2 cm long. The fresh rocks are black and have a high lustre. The weathered surface may have a "salt-and-pepper" texture. The metagabbro is strongly sheared at southeastern Carghill Island.

Under the microscope it appears that all primary minerals have been completely replaced. Brown pleochroic hornblende, (probably pseudomorphous after clinopyroxene), is rimmed by colourless to light green amphibole, which also makes up most of the groundmass, with chlorite and minor quartz. Plagioclase phenocrysts are almost completely replaced by clinozoisite. Ilmenite-magnetite skeletons are surrounded by masses of leucoxene.

UNIT 13: GABBRO AND DIABASE

Mafic dykes of unit 13 occur sporadically throughout the map area. The dykes are part of the Molson and Mackenzie swarms (Fahrig et al., 1965; Scoates and Macek, 1978), which occur abundantly outside the map area to the west and north, nearer the margin of the Superior Province. The average trends of the Molson and the younger Mackenzie dykes are respectively northeast and northwest. In this report, the dykes are grouped together because only about seventeen dykes and sets of dykes were mapped and age relationships between them have not been established. An Aphebian age has been proposed for the Molson dykes by Hubregtse (1978) and others. Ermanovics and Fahrig (1975) concluded that the Molson dykes have a tholeiitic, low alkali basaltic composition. Macek and Scoates (1978) suggest that the Molson dyke magma had a definite komatiitic affinity.

The dykes vary in width from a few centimetres to at least 50 m. The largest dykes were mapped in the vicinity of Peridotite Island in the Carrot River area. An olivine-hornblende gabbro was traced over 6 km in a west-southwesterly direction from the northern shore, opposite the eastern tip of Peridotite Island, along the northern shore of the same island, swinging into a southwestern direction at the western tip of Peridotite Island. The dyke was located again in the metatonalite terrain south of Carrot River. A coarse grained olivine norite dyke was documented just south of the eastern tip of Peridotite Island. Smaller dykes occur scattered throughout the Lynx Bay and Carrot Point area, south of Carrot River and in the tonalitic gneiss terrain to the north. A few diabase dykes were mapped on the islands between Traverse Island and Carghill Island.

PETROGRAPHY

This unit comprises gabbro, olivine gabbro and olivine norite. The rocks are medium- to fine-grained, and dense greyish-black. Their dull appearance distinguishes them from the lustrous amphibole-rich, older, metamorphosed mafic dykes. Coarser grained dykes have a speckled appearance. Aphanitic chilled margins with small phenocrysts (up to 2 mm) of olivine, plagioclase and pyroxene were documented locally. The rocks have knife-sharp, straight-walled contacts with the country rocks and show no signs of post-crystalline deformation. In thin section it appears that deuteric alteration commonly resulted in extensive replacement of the primary mineralogy. However, since the Molson dykes near the Superior-Churchill Province boundary have been affected by Hudsonian metamorphism (Hubregtse, 1980) the Molson dykes of the Oxford Lake area may also have been affected by weak Hudsonian metamorphism.

The primary mineralogy comprises calcic plagioclase, clinopyroxene, hornblende, orthopyroxene, biotite, olivine, magnetite-ilmenite and quartz.

Plagioclase forms idiomorphic laths in the fine grained diabases, yielding the typical dolerite texture. Stubby, tabular carlsbad-albite twinned plagioclase (An_{85-97}) is part of the gabbroic texture. Clinopyroxene with the optical properties of augite and titanaugite ($\gamma/\Lambda_c = 43°$, $\delta = 0.022$) forms pink pleochroic poikiloblastic aggregates enclosing plagioclase. The aggregates may show simplectic vermicular intergrowths of individual augites. Diallage and salite structures are common, as are hourglass-and-sector intergrowths.

Orthopyroxene forms stubby single crystals, surrounded by augite in the gabbros. The orthopyroxene appears to be a bronzite (δ = 0.010, 2V: neg.). Only one olivine-biotite norite has been found.

Olivines form rounded grains and are usually partially or completely replaced by iddingsite, magnetite, serpentine, bowlingite, and carbonate, even in otherwise fresh rocks. Fresher olivinas contain opaques and a kelyphytic rim of serpentine.

Primary hornblende and reddish-brown biotite form interstitial aggregates. The hornblende typically exhibits a reddish-brown pleochroic core with an olive-green pleochroic rim. Skeletal and solid grains of magnetite-ilmenite are common constituents. Quartz may be present as an interstitial phase, locally forming graphic intergrowths with plagioclase. Apatite is a conspicuous idiomorphic accessory.

The primary mineralogy of most dykes is variably altered. The larger dykes contain both fresh and altered domains. In thin section it appears that the fine grained and chilled margins are void of alteration features, whereas the coarser grained centres of the dykes contain conspicuous amounts of secondary minerals. This observation and the lack of post-crystalline deformation suggests deuteric post-crystalline alteration caused by late-magmatic phases, rather than by fluid transfer from the country rock.

In addition to the alteration products of olivine, the secondary mineralogy includes chlorite, light green and colourless amphibole, leucoxene and saussurite minerals. In extreme cases the pyroxenes and primary hornblendes are replaced by felted masses of chlorite and colourless amphibole. Bronzite yields talc with bastite structure. Plagioclase may be completely replaced by sub-microscopic dusty aggregates of saussurite minerals. Leucoxene replaces ilmenite-magnetite.

It is difficult, particularly on the outcrop, to distinguish severely altered diabases from weakly metamorphosed, non-deformed older mafic dykes and sills of units 1e, 4h, 5f and 7h, as the secondary mineralogy of the gabbros and the metamorphic low-grade mineral assemblages of the metagabbros are very similar. In thin section, however, it is clear that recrystallization of the fine grained alteration phases, such as chlorite-amphibole and saussurite aggregates, has not occurred in the gabbros and diabases of unit 13. Whereas recrystallized granular aggregates of clinozoisite and muscovite display either blastesis or granoblastic aggregates in the metagabbros, they form pseudomorphic aggregates after primary phases in the non-metamorphosed gabbros.

Figure 62: Overleaf ——→

96°18'
55°00'

LEGEND

ZONE		METAMORPHIC EVENT
E		M_2, POST - OXFORD LAKE GROUP METAMORPHISM
F		
G		
H		
A		M_1, PRE - OXFORD LAKE GROUP METAMORPHISM
B		
C		
D		

ZONES UNDERLAIN BY ISLETS ONLY ARE LABELLED WITH LETTERS.

- SAMPLE LOCATION
- GARNET
- DIOPSIDE
- ANDALUSITE ± STAUROLITE
- ANTHOPHYLLITE ± CORDIERITE
- CHLORITOID
- KYANITE

APPROXIMATE LIMIT OF OCCURRENCE OF QUENCH CRYSTALS IN META - BASALT

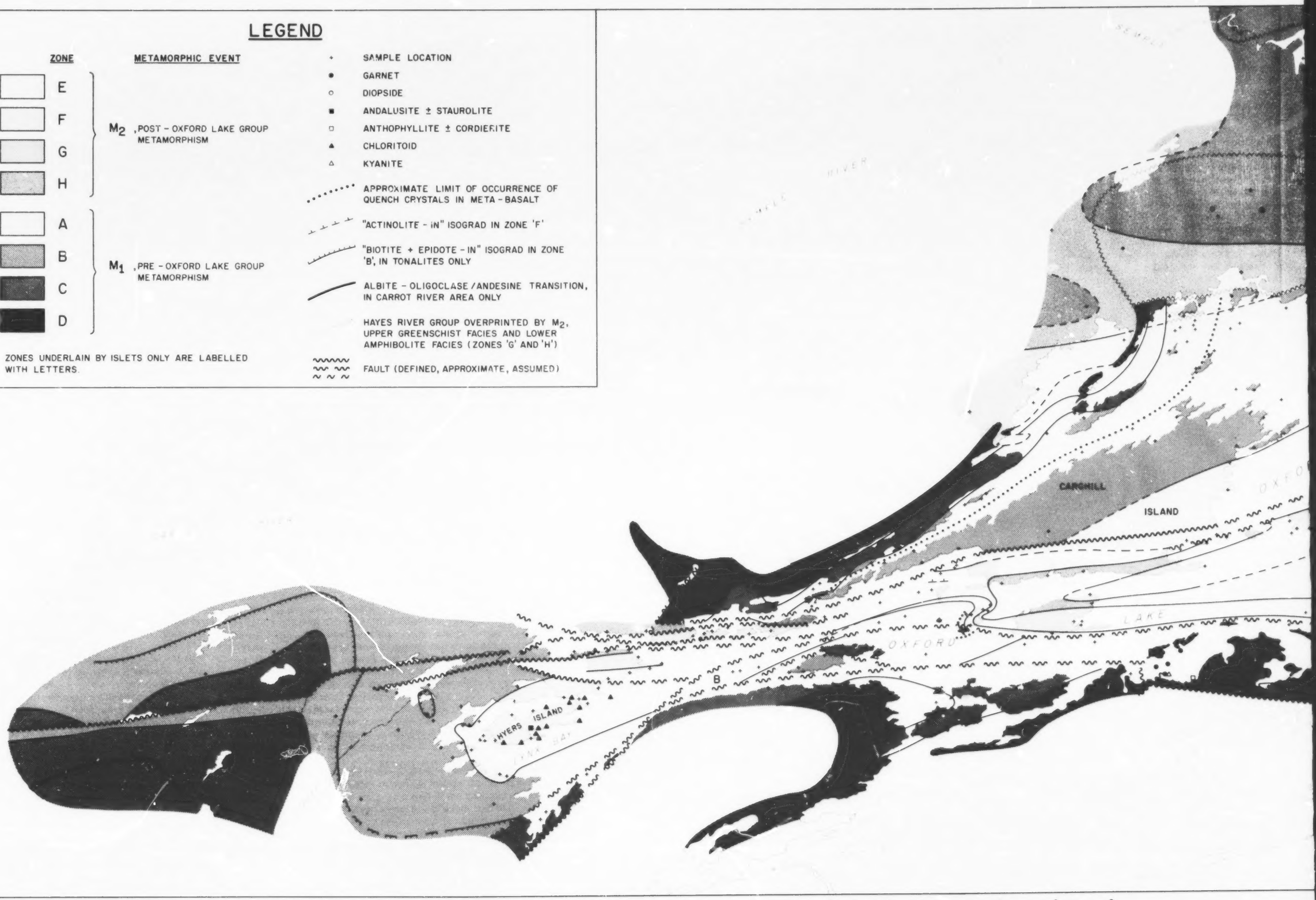
"ACTINOLITE - in" ISOGRAD IN ZONE 'F'

"BIOTITE + EPIDOTE - IN" ISOGRAD IN ZONE 'B', IN TONALITES ONLY

ALBITE - OLIGOCLASE / ANDESINE TRANSITION, IN CARROT RIVER AREA ONLY

HAYES RIVER GROUP OVERPRINTED BY M_2, UPPER GREENSCHIST FACIES AND LOWER AMPHIBOLITE FACIES (ZONES 'G' AND 'H')

FAULT (DEFINED, APPROXIMATE, ASSUMED)



54°43'
96°18'

2 0 2 4 6 8
KILOMETRES

95°12'
55°00'

SEMPLE

RIVER

SEMPLE BAY

BACK LAKE

OXFORD HOUSE

G

G

LAKE

CANSHILL ISLAND

OXFORD

JACKSON BAY

LAKE

OXFORD

B

MICHAYABISH LAKE

CARTOGRAPHY BY : DAVE MCSHANE

54°43'
95°12'

2 0 2 4 6 8
KILOMETRES

Figure 62: Metamorphic zones of the Oxford Lake area.

Figure 62: Metamorphic zones of the Oxford Lake area.

METAMORPHISM

Introduction

The major metamorphic zones of the Oxford Lake area are shown in Figure 62. Mineral assemblages of the supracrustal Hayes River Group and Oxford Lake Group rocks generally indicate greenschist facies (or low-grade) metamorphism. Noteworthy rocks of this facies are the chloritoid-bearing schists of the Hyers Island region. Amphibolite facies (or medium-grade) metamorphic rocks are more rare and occur mainly in narrow, linear, often fault-bounded zones, such as the southern shore of Oxford Lake. Another area of amphibolite facies rocks can be traced from Stubbs Lake, 8 km northwest of Oxford House, to the west end of Knee Lake and Magill Lake (see Gilbert, in prep.). The former two zones are underlain exclusively by rocks of the Hayes River Group and the Bayly Lake Complex. The Stubbs Lake-Knee Lake zone, however, is underlain by members of both the Hayes River Group and the Oxford Lake Group. Cursory examination of the zones mentioned above may (erroneously) lead to the conclusion that both the Hayes River Group and the Oxford Lake Group rocks were subjected to metamorphism with comparable P-T ratio and thus it was assumed that both the Hayes River Group and the Oxford Lake Group were affected by the same post-Oxford Lake Group orogenic event. Alternatively, evidence will be presented that at least some of the metamorphism which affected the Hayes River Group rocks was caused by a pre-Oxford event.

It will also be shown that the metamorphism affecting the Oxford Lake Group and some of the Hayes River Group was intermediate to Abukuma and Barrovian type (Winkler, 1967). Mineral assemblages of certain Hayes River Group rocks point to a higher P-T ratio for the pre-Oxford event. It is inferred from the mineral assemblage of the highest-grade metapelitic rocks that the peak P-T conditions of the post-Oxford metamorphism were about 4 kb and 635° C, respectively.

Evidence for a pre-Oxford Lake Group metamorphic event

Evidence for an unconformable relationship between the Hayes River and Oxford Lake Groups was presented previously. The strongly penetrative post-Oxford deformation obliterated evidence for a pre-Oxford event, including earlier metamorphic minerals, such as garnet, staurolite, alumina silicates, etc. However, certain features (reviewed below) can be attributed to a pre-Oxford event.

KYANITE IN THE HAYES RIVER GROUP

Kyanite relicts, armoured by cordierite, were observed in a sillimanite-biotite-cordierite gneiss (Gilbert, in prep.). The rock is associated with an anthophyllite-cordierite- biotite-bearing gneissic metawacke (unit 2f) which occurs in a felsic pyroclastic sequence of the Hayes River Group between Knife Lake and Gods Lake.

Kyanite was also recorded from Cat Eye Bay in a biotite quartzite, associated with anthophyllite-cordierite gneiss (2f) of the Hayes River Group. The origin of the kyanite-biotite quartzite is not clear, but it could be part of the alteration zone associated with the sulphide mineralization in Cat Eye Bay.

The presence of kyanite is indicative of intermediate-pressure metamorphism in excess of 4 kb.

AMPHIBOLITE-PLAGIOCLASE RELATIONSHIPS

The Oxford Lake Group contains stable associations of albite + colourless amphibole, and oligoclase-andesite + deep blue-green amphibole (Fig. 62), suggesting Abukuma-type regional metamorphism (Winkler, 1967). Similar relationships are found in some Hayes River Group rocks. However, pre-Oxford Lake Group metabasalts and metatonalites containing deep blue-green amphibole + albite assemblages occur along the southern shore of Oxford Lake between Cat Eye Bay and the Carrot River region. The albite + blue-green amphibole pair is indicative of metamorphism governed by a higher P-T ratio than the Abukuma type, according to Winkler (1967). Kyanite, mentioned above, was found in the same zone. Blue-green amphibole and albite also characterize the Hayes River Group metabasalts along the northern shore of Oxford Lake.

METAMORPHIC FRAGMENTS

In a few locations the Oxford Lake Group conglomerate contains clasts that were deformed prior to their deposition. Foliated metabasalt fragments were documented at Chataway Lake (Marten, 1973) and at Gods Lake (Gilbert, in prep.). A layered gneissic tonalite boulder was observed in the mixed pyroclastic-epiclastic Traverse Island sequence at Traverse Island.

Gilbert (in prep.) has documented gneissic, mafic and amphibolite xenoliths, supposedly derived from the Hayes River Group, in tonalite dykes (unit 6) in the Michikinabish Lake area and in the Elk Island pluton (unit 7), respectively. The gneissosity was developed before their incorporation into the dyke. This suggests an orogenic event prior to intrusion of the syn- to late-tectonic plutonic rocks of the Bayly Lake Complex.

METAMORPHIC ZONATION AND STRUCTURAL TRENDS OF THE HAYES RIVER GROUP AND THE OXFORD LAKE GROUP

The configuration of the metamorphic zones within the Hayes River Group and the Oxford Lake Group are distinctly different. The metamorphic grade of the Hayes River Group increases generally with stratigraphic depth, that is, towards the margins of the greenstone belt and towards the tonalitic plutons. The metamorphic zonation within the Oxford Lake Group is less regular and the highest grade occurs in the centre of the belt (Fig. 62). This pattern is particularly well developed between Oxford Lake and Knee Lake. Contrasting structural directions of the Hayes River Group, mainly easterly-trending, are also obvious in the Oxford Lake area, suggesting different geological evolutions.

PRELIMINARY CONCLUSIONS

The evidence presented above suggests that the Oxford Lake area was affected by two major metamorphic events. An earlier period of relatively high-pressure metamorphism predated the deposition of the Oxford Lake Group, and a later event, postdating the Oxford Lake Group, was governed by relatively high-temperature low-pressure metamorphism. The erasing effect of the penetrative post-Oxford event may be responsible for the scarcity of pre-Oxford metamorphic and structural features.

Metamorphic histories are commonly based on studies from rocks of pelitic and semipelitic composition. Such rocks are abundant within the Oxford Lake Group but rare within the Hayes River Group. However, as will be shown in the next sections, the metamorphic

history can also be derived from the metamorphic mineral assemblages of mafic and intermediate rocks of the Hayes River and the Oxford Lake Groups.

Pre-Oxford Lake Group metamorphism - M_1

Evidently only the Hayes River Group and the Bayly Lake Complex were affected by this period of metamorphism and related tectonism.

Data pertinent to the metamorphism of the pre-Oxford event are derived from the area west of a boundary from Cat Eye Bay, through Eight Mile Point, to Semple Bay and Semple Lake (Fig. 62).

The relationships between metamorphic and deformational events, that affected the Oxford Lake-Carrot River area, are shown in Table 8.

During the first metamorphic event (M_1) greenschist facies conditions dominated most of the area. Amphibolite facies conditions prevailed along the margins of the greenstone belt.

NORTHERN OXFORD LAKE

The grade of metamorphism increases gradually from the lower greenschist facies to the middle amphibolite facies with stratigraphic depth in the south-facing Hayes River Group that underlies the northern half of Oxford Lake. Major metamorphic zones are shown in Figure 62. Rocks in the area northwest of Eight Mile Point are hardly deformed and original quench textures in metabasalts are well preserved (Figs. 14 and 62). The original mineralogy has been replaced by a metamorphic assemblage, except for plagioclase in some instances. Non-saussuritized plagioclase microphenocrysts have locally retained high anorthite contents (An_{80-86}). Quench plagioclases are commonly clear and unaltered. Their small size precluded optical determination of their composition. Although labradorite was preserved, perhaps metastably, the conditions were apparently those of the greenschist facies. Pumpellyite and prehnite have not been identified in the Hayes River Group at Oxford Lake.

The lowest grade of metamorphism within the Hayes River Group sequence was detected in its uppermost part, zone A in Figure 62, which is a 2 km wide succession of pillowed metabasalt that underlies east-central Carghill Island and Kanawastiwiwin Island. Actinolite is absent in this zone. The critical assemblage is:

chlorite + carbonate + quartz + albite + white mica.

The rocks are marked by porphyroblastic growths of carbonate and, to a lesser degree, white mica. Random carbonate tablets give the rock a pseudoporphyritic appearance, that almost obliterates the vaguely discernible original quench textures. Actinolite appears with the disappearance of porphyroblastic carbonate, most likely as a result of the following reaction:

dolomite + quartz + $H_2O \rightleftharpoons$ tremolite + calcite + CO_2.

The "actinolite-in" isograd separates zone A from zone B in Figure 62.

The accompanying deformation is not noticeable northwest of Eight Mile Point. A foliation parallel to S_0 is evident with increasing metamorphic grade and is well developed in the western Carghill Island area. The early foliation is locally overprinted by the post-Oxford event (M_2) in the area between Kwaykwaychi Bay, Wapaskosowakow Lake and Semple Lake.

The next zone B is marked by the association:

actinolite + chlorite + epidote + albite + quartz.

Zone B is about 4.5 km wide and underlies most of Carghill Island and Semple Bay peninsula. Quench textures and pseudomorphs after microphenocrysts are perfectly preserved in this zone (Fig. 14).

TABLE 8
Tectonic and Metamorphic Events in the Oxford Lake-Carrot River Area

Deformation	Structural Elements		Orientation	Metamorphism
	Hayes River Group and Bayly Lake Complex	Oxford Lake Group and units 11 & 12		
	S_s, bedding			
D_m-1	S_m-1, mylonite		subhorizontal?	M_1
		S_s, bedding		
D_m	F_m, monoclines parasitic Z & S folds	F_m, synclinorium parasitic Z & S folds	subvertical	M_2
	S_m, main foliation	S_m, main foliation	E-W to SW-NE	
D_m+1	dextral wrench faults		E-W to WSW-ENE subvertical	
D_m+2	sinistral wrench faults		E-W to SW-NE subvertical	
	F_m+2 major cross folds and drag folds			
	F_m+2, minor Z & S folds			
	S_m+2, axial planar foliation		WSW-ENE subvertical	

Blue-green amphibole replaces actinolite in zone C, in which the following mineral assemblage is critical:

blue-green amphibole + chlorite + epidote + albite + quartz.

Zone C varies in width, but averages about 1 km.

Subsequently chlorite becomes unstable. In zone D the assemblage:

blue-green amphibole + epidote + albite + quartz is stable. Its width is difficult to estimate, due to lack of continuous outcrop and superimposed M_2 structures. The western end of the zone may be as wide as 4 km. Oligoclase/andesine was formed at the expense of albite with the disappearance of chlorite in the metabasalts near Kwaykwaychi Bay. The stable association: blue-green amphibole + oligoclase/andesine, however, occurs in an area which is strongly overprinted by the post-Oxford event, M_2. It is inferred that albite + blue-green amphibole was the stable association during the M_1 event in the lower-grade part of the chlorite-free zone D. Evidence for this was also found in the Hayes River Group sequence of southern Oxford Lake. Garnet, diopside, and scapolite were formed in rocks of suitable composition within zone D (Fig. 62).

The "actinolite-in", "actinolite-out" and "chlorite-out" isograds (Fig. 62) trend generally parallel to the original layering and F_{1A} structure. The appearance of brown biotite in rocks of suitable composition nearly coincides with the "actinolite-out" isograd.

SOUTHERN AND WESTERN OXFORD LAKE

The southern sequence of the Hayes River Group differs from the northern succession in that it is truncated by several major wrench faults. As a result the metamorphic zonation is not as well preserved as in the northern section, but changes in metamorphic grade are still detectable within the fault-bounded slices of Hayes River Group and tonalitic rocks that underlie Cat Eye Bay and Lynx Bay. The Cat Eye Bay-High Rock Island slice is bounded by an older dextral fault in the south and a younger sinistral wrench fault in the north. The sinistral fault swings towards the southeast into Lynx Bay, separating The Cat Eye Bay-High Rock Island fault slice from the Lynx Bay supracrustal rocks. It is inferred that Lynx Bay, High Rock Island and northern Cat Eye Bay once belonged to one continuous crustal section. Garnet-bearing rocks northeast of Cat Eye Bay joined up initially with the garnet-bearing rocks of southwestern Cat Eye Bay, prior to the major dextral displacement along the Hayes River Group-Bayly Lake Complex interface, which created the superposition of the two slices of Hayes River Group rocks (see also Structure).

Penetrative retrogression that accompanied subsequent shearing and mylonitization, resulted in a spotty distribution of mineral assemblages indicative of amphibolite facies conditions.

The weakest metamorphism recognizable in the area, Zone A, coincides with the Hyers Island-Lynx Bay region (Fig. 62). The critical assemblages are:

chloritoid + chlorite + (ferro-) carbonate + sericite + quartz; and
chlorite + carbonate + sericite + quartz (± albite).

Chloritoid was only generated in pyroclastic and volcanogenic rocks of suitable composition, that were strongly hydrothermally alterated. It has been shown earlier that the carbonate phase which co-existed with chloritoid must have been an iron carbonate.

The metamorphic zonation centres around Lynx Bay. An increase in metamorphic grade in a westerly direction is marked by the appearance of epidote in tonalitic rocks and epidote + actinolite in mafic rocks (Fig. 62). The width of zone B, bounded by the "actinolite-in" and "actinolite-out" isograds, is approximately 5 km. The higher-grade part of the zone is characterized by the presence of biotite in the tonalitic rocks. Albite is stable in the lower-grade part of the zone C, which is not in agreement with the findings in the Oxford Lake area. It is not known whether this discrepancy is caused by a change in whole-rock composition or local metamorphic conditions, due to lack of geological control in this area of sparse exposure.

The metamorphic grade also increases eastwards from Lynx Bay. The "actinolite-out" isograd is located near High Rock Island. The "chlorite-out" isograd is situated east of Thomsen Island. Quench textures survived metamorphism in the High Rock Island area, on the low-grade side of the "chlorite-out" isograd.

Chlorite-free garnet, anthophyllite, cordierite and cummingtonite-bearing rocks occur near Cat Eye Bay in the area with the highest grade of metamorphism. Rare kyanite-bearing quartzites have also been documented in zone D (Gilbert, pers. comm.). The quartzites exhibit a granulite-like texture and contain abundant stubby kyanite (Fig. 63), which is part of an older assemblage that includes biotite, quartz, minor muscovite and rutile.

The "chlorite-out" isograd is relatively well defined within the tonalite complex in the region of the Hayes River inlet into Oxford Lake. It appears that albite + blue-green amphibole is stable on both sides of the "chlorite-out" isograd. Albite + blue-green amphibole was also documented in chlorite-bearing rocks within the smaller fault-bounded blocks of southern High Rock Island and Lynx Bay.

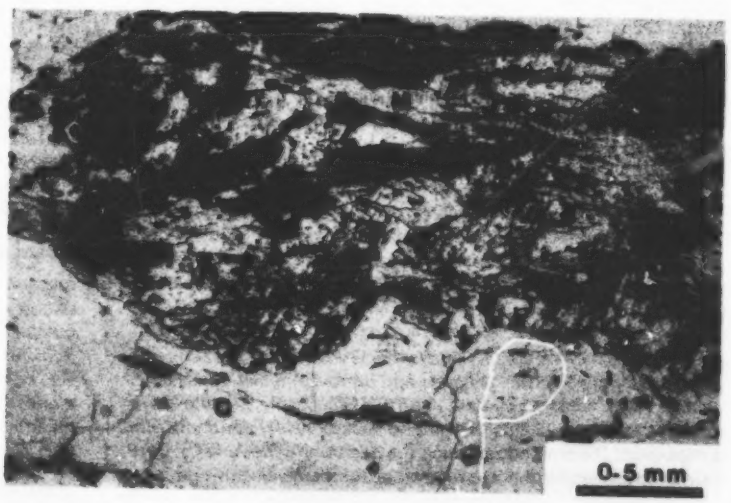


Figure 63:
Kyanite (grey)-plagioclase (striated)-muscovite aggregate surrounded by quartz (large grains) in kyanite quartzite from Cat Eye Bay.

Calc-silicate gneisses with peculiar mineralogical compositions occur as layers within metabasalts 3.5 km east of Cat Eye Bay. The main constituents are garnet, anorthite, actinolite, clinozoisite, quartz and white mica, with minor amounts of biotite, cummingtonite, magnetite, pyrite and tourmaline. Although the calc-silicate rocks occur within the chlorite-free zone D, they also contain abundant chlorite. Figure 64 shows the earliest mineral assemblage: anorthite + actinolite + chlorite, which overgrew a well-developed magnetite fabric during the main phase of M_1. The anorthite porphyroblasts (93% An; J. Peters, pers. comm.) display closely spaced twin-lamellae. Idiomorphic late- to post-tectonic growth of garnet followed shortly afterwards. Subsequently anorthite broke down to clinozoisite + muscovite, or, combined with actinolite, to clinozoisite + chlorite. Garnet + actinolite pairs became unstable and formed chlorite. Stable assemblages of garnet + clinozoisite + chlorite and clinozoisite + actinolite + chlorite, both including white mica, quartz, biotite and magnetite, were thus formed as a result of the post-tectonic anorthite breakdown.

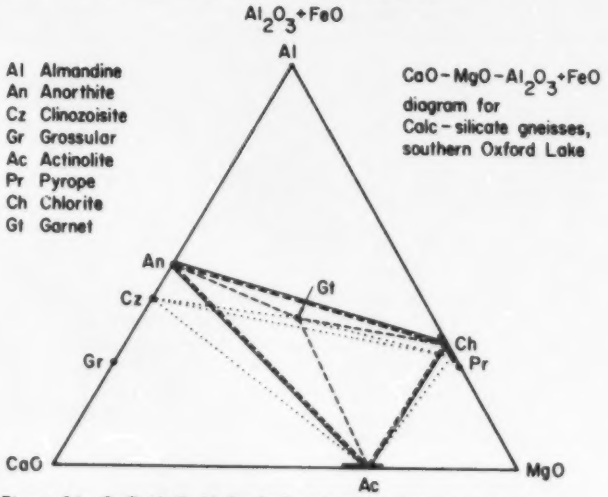


Figure 64. CaO-MgO-Al_2O_3+FeO diagram; full lines: earliest assemblage; dashed lines: late- to post-tectonic assemblages; dotted lines: assemblages resulting from anorthite breakdown.

The cordierite-anthophyllite gneisses of southern Cat Eye Bay are also anomalous for the intermediate to high-pressure type pre-Oxford Group metamorphism. The presence of cordierite suggests a higher geothermal gradient. This telescoping effect of metamorphic facies is attributed to a rise in temperature caused by the intrusion of the late-tectonic Cat Eye Bay tonalite (unit 7). The metamorphic textures of the cordierite-anthophyllite gneisses are indeed indicative of late- to post-tectonic mineral growth.

PRESSURE-TEMPERATURE CONDITIONS

The assemblage:

albite + blue-green amphibole

is typical of P-T conditions of the intermediate pressure of the Barrovian facies series during regional metamorphism indicating higher P-T ratios than those of the low pressure Abukuma facies series (Miyashiro, 1967; Winkler, 1967).

Critical mineral assemblages of the pre-Oxford facies series are plotted in Figure 65. The Abukuma and Barrovian facies series, after Winkler (1967) and Van de Kamp (1970), respectively, and the facies series of the Central Alps (Wenk and Keller, 1969), are shown for comparison. The pre-Oxford series, the Barrovian series and the Central Alpine series have the following critical characteristics in common: firstly, the occurrence of chloritoid in greenschist facies rocks of suitable composition; secondly, the occurrence of blue-green amphibole and albite in chlorite-bearing rocks; and thirdly, the presence of kyanite in amphibolite facies rocks. The three features mentioned have not been documented in the Abukuma-type facies series. One significant difference between the Barrovian and the Central Alpine series, and pre-Oxford facies series is the stable occurrence of blue-green amphibole and albite in chlorite-free rocks. According to Winkler (1967) and Wenk and Keller (1969), chlorite becomes unstable with the appearance of oligoclase/andesine at the expense of albite in the Barrovian and Central Alpine facies series. In the pre-Oxford facies series, chlorite remains stable in andesine + blue-green amphibole-bearing rocks, but disappears before garnet and diopside are formed.

The distribition of metamorphic indicator minerals shown in Figure 62 illustrates the change in conditions from lower greenschist facies to middle amphibolite facies. The present width of the Hayes River Group in the area northeast of Carghill Island is approximately 13 km which may account for a pressure difference of about 3.5 kb between the presently exposed base and top of the Hayes River Group. If it is assumed that the temperature of the lowest metamorphic facies zone A was about 300°C, then a pressure increase of 3.5 kb under intermediate P-T gradient would result in the formation of kyanite in the highest-grade rocks of suitable composition (Fig. 66). If the Hayes River Group was subjected to a lower P-T gradient, sillimanite would have been the stable alumina silicate phase. Since kyanite, and not sillimanite, was documented, it is inferred that the early pre-Oxford event, M_1, was characterized by a considerably higher P-T ratio, than the more common ratios of low-pressure facies series found in Archean greenstone belts.

Post-Oxford Lake Group metamorphism - M_2

The M_2 metamorphism affected all rock units except unit 13. The effects of the M_2-metamorphism are best reflected by the mineral assemblages of the Oxford Lake Group rocks (units 8, 9 and 10) and the syn-tectonic granodiorite of unit 11. The intensity of M_2 varied considerably.

The M_2 metamorphism reached its highest grade in the eastern Oxford Lake region which is underlain by the Oxford Lake Group, metagranodiorite of unit 11 and rocks of the Hayes River Group. The previously metamorphosed Hayes River Group rocks were overprinted by M_2 under amphibolite facies conditions. The metamorphic zonation (Fig. 62) is complex in the Semple Bay-Kwaykwaychi Bay region. Conditions during M_2 had to be amphibolite facies grade in order to have a noticeable effect on the M_1 mineral assemblages. The rather abrupt truncation of the northeast-trending M_1 zonation by the east-trending M_2-amphibolite facies zones is accompanied by a sudden emergence of an east-trending F_2-foliation and the disappearance of primary features such as quench textures in the M_1-greenschist facies zones. However, small enclaves of non-overprinted and upgraded rocks may occur north and south of the overprinting amphibolite facies isograd, respectively. M_2-greenschist facies conditions may have prevailed in the area south of the M_2-amphibolite facies zone, but cannot be distinguished from retrogression related to either M_1 or M_2.

Figure 62 shows that the lowest grade of M_2 metamorphism was reached in the Oxford Lake Group rocks adjacent to the Hayes River Group, along the margins of the synclinorial succession that underlies central Oxford Lake between Eight Mile Point, Jackson Bay and High Rock Island. The southern low-grade region is underlain by the lower section of the sedimentary subgroup of the Oxford Lake Group. The highest grade of M_2 metamorphism affected the central part of the area underlain by the Oxford Lake Group. The configuration of metamorphic zones indicates relatively high heat flow in the axial zone of the remaining Oxford Lake Group depositional basin. This part of the

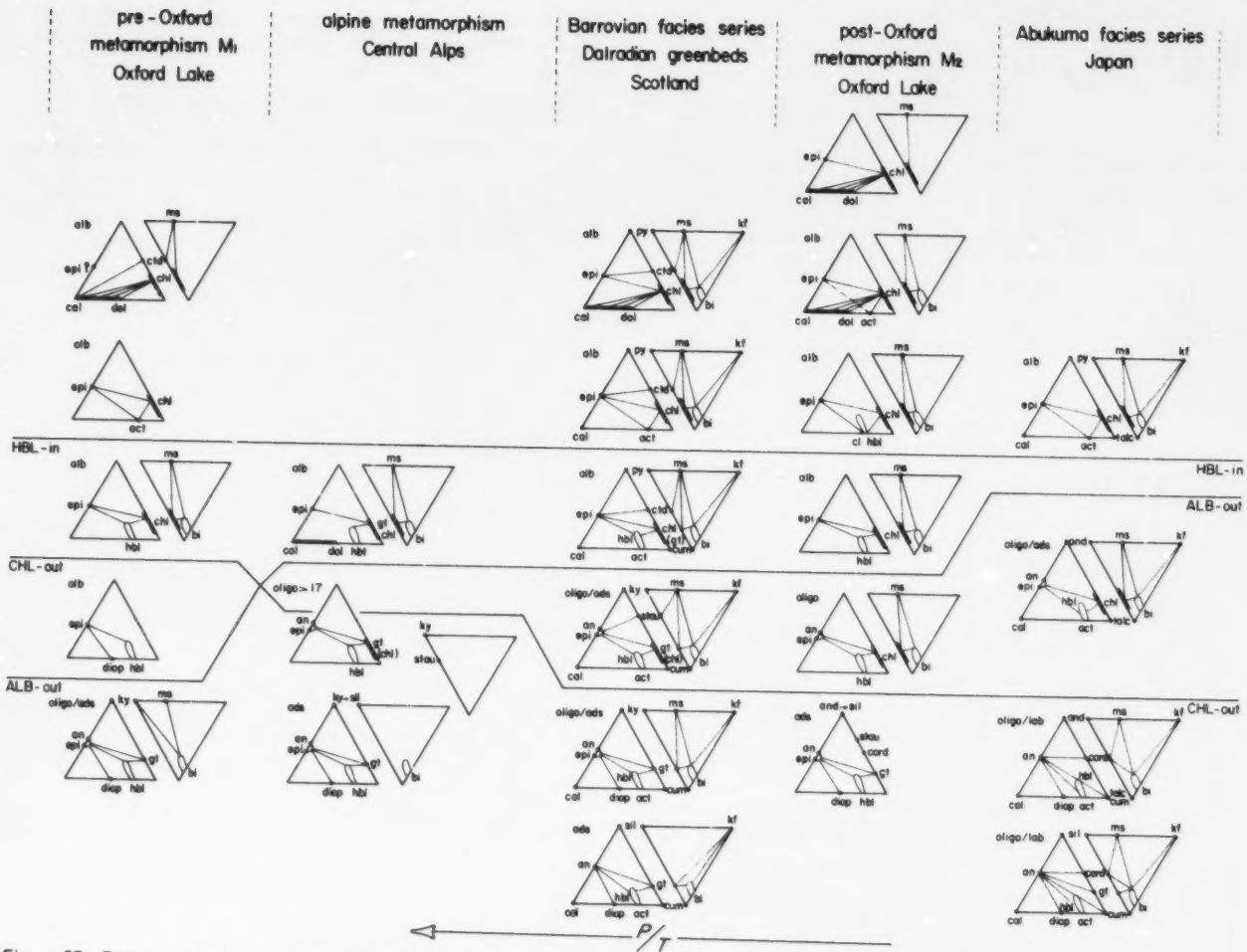


Figure 65: Diagram showing minerals and stable mineral assemblages typical for the pre-Oxford and post-Oxford metamorphic events, the Barrovian (Van de Kamp, 1970) and Abukuma (Winkler, 1967) facies series and the alpine metamorphism of the Central Alps (Wenk and Keller, 1969).

Abbreviations: alb: albite; oligo: oligoclase; ads: andesine; an: anorthite; kf: potassium feldspar; epi: epidote; cal: calcite; dol: dolomite; py: pyrophyllite; and: andalusite; sill: sillimanite; ky: kyanite; chl: chlorite; ms: muscovite; bi: biotite; hbl: hornblende; cl.hbl: colourless hornblende; act: actinolite; cumm: cummingtonite; diop: diopside; gt: garnet; stau: staurolite; cord: cordierite; ctd: chloritoid.

Subordinate minerals between brackets. Compositions of the co-existing plagioclases are shown in the upper left-hand corners of the diagrams.

basin appears to have been the centre of volcanism during the early depositional history of the Oxford Lake Group and of subsequent syn-to late-tectonic intrusion (unit 11). The pattern of metamorphic zones of the Oxford Lake Group contrasts with that of the Hayes River Group, in that the latter group's metamorphic configuration shows an increase in metamorphism with stratigraphic depth.

Characteristic mineralogical assemblages for rocks of the Oxford Lake Group and Unit 11 are shown in Figure 63.

Rocks of the lower greenschist facies (zone E, Fig. 62) are characterized by the association: chlorite + saussurite + quartz + albite + carbonate (+ epidote). The appearance of biotite marks the transition into the upper greenschist facies (zone F). Actinolite or colourless amphibole becomes stable in rocks of appropriate composition on the high-grade side of the biotite isograd. Biotite and amphibole, however, have not been found to co-exist in this zone. The typical assemblages of zone F are biotite + chlorite + saussurite + albite + quartz and amphibole + chlorite + saussurite + albite + quartz.

Zone G is characterized by the co-existence of biotite and blue-green amphibole. The plagioclase composition changes from albite to oligoclase/andesine within this zone. The typical assemblages are amphibole + biotite + chlorite + quartz + albite or oligoclase/andesine + epidote.

The highest grade rocks in zone H are chlorite-free assemblages that may include garnet, diopside, garnet + andalusite and staurolite + andalusite. Garnet + cordierite, sillimanite, garnet + cummingtonite and cummingtonite + hornblende are reported by Gilbert (in prep.) from the southeastern extension of the Oxford Lake Group, in southwestern Knee Lake.

Chlorite, saussurite and epidote were formed during a phase of retrogressive metamorphism, partially replacing previously formed

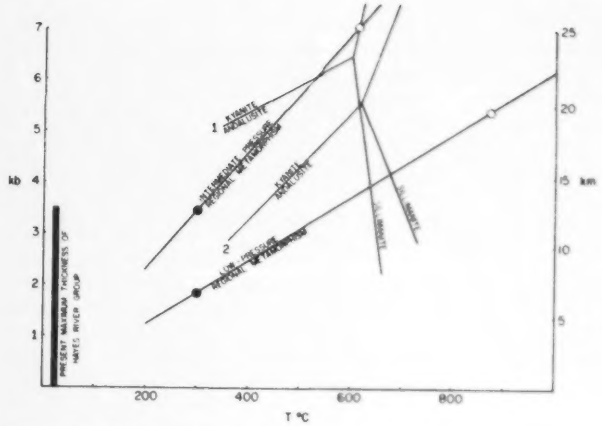


Figure 66: P-T diagram showing gradients for low-pressure and intermediate pressure metamorphism. Full circles and open circles represent possible metamorphic conditions for the presently exposed bottom and top of the Hayes River Group sequence, respectively. See text for explanation. Aluminum silicate reaction curves 1 and 2 after Althaus (1967) and Richardson, Gilbert and Bell (1969), respectively.

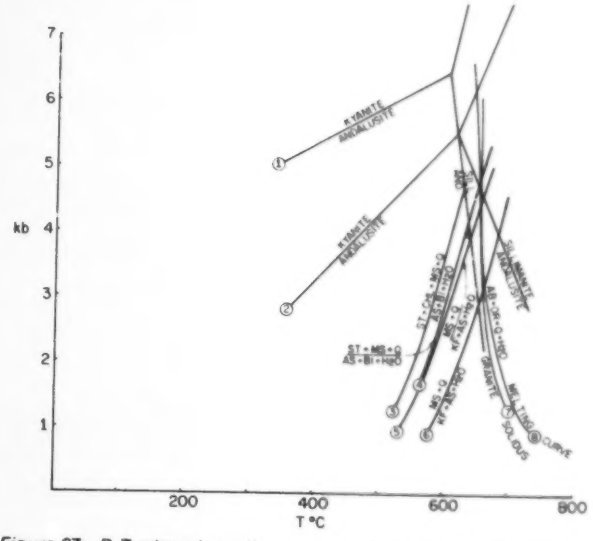


Figure 67: P-T mineral reaction curves related to the post-Oxford metamorphism (M_2). The conditions of the climax of M_2 are indicated by the solid square.
Abbreviations: St: staurolite; Ms: muscovite; As: aluminum silicate; Bi: biotite; Chl: chlorite; Kf: potassium feldspar; Ab: albite; Or: orthoclase.
Curves are after: 1. Althaus (1967); 2. Richardson, Gilbert and Bell (1969); 3. Guidotti (1974); 4. Hoschek (1969); 5. Evans (1965); 6. Althaus et al. (1970); 7. Piwinskii (1968); 8. Luth, Jahns and Tuttle (1964).

assemblages that include garnet, amphibole, staurolite and andalusite. The retrogression is of minor significance and its associated mineral growth is generally post-tectonic.

PRESSURE-TEMPERATURE CONDITIONS

Figure 67 shows experimental temperature-pressure reaction curves for mineral associations related to the M_2 metamorphism. Staurolite breakdown reactions resulting in the formation of andalusite and biotite (Hoschek, 1969; Guidotti, 1974) were documented in metasediments 3.5 km west of Forestry Point. Andalusite is the prevailing alumina silicate. Gilbert (in prep.) describes rare sillimanite in andalusite, in rocks of the Oxford Lake Group southwest of Knee Lake, indicating that the high-temperature end of the post-Oxford facies series just intersected the andalusite/sillimanite reaction curve. Breakdown reactions of muscovite in the presence of quartz, resulting in the formation of potassium feldspar and alumina silicate (Evans, 1965; Althaus et al., 1970) were not active during the M_2-episode. The absence of partial melting of the Oxford Lake Group metasediments further constrains P-T conditions. Thus, a temperature of approximately 635°C and a pressure of about 4 kb can be inferred for the high-grade end of the post-Oxford metamorphism.

The diagnostic minerals of the M_2-episode are shown in Figure 65, for comparison with diagnostic assemblages of the Abukuma facies series (Winkler, 1967), Barrovian facies series (Van de Kamp, 1970), the central Alpine facies series after Wenk and Keller (1969) and the pre-Oxford facies series. The main difference between the post-Oxford and the Abukuma facies series is that the albite-oligoclase/andesine transition takes place on the high-grade side of the actinolite-hornblende isograd in the post-Oxford series, whereas the same transition lies in the actinolite stability field in the case of the Abukuma facies series. The significant difference between the Barrovian facies series and the post-Oxford facies series is the presence of cordierite and the lack of kyanite in the latter.

The most important relationship in Figure 65 is the discordant relationship between the albite-oligoclase/andesine isograd and the chlorite-out and hornblende-in isograds. The albite-oligoclase/andesine transition takes place at lower pressures with increasing geothermal gradients. This relationship was an effective tool to recognize and distinguish different types of metamorphism in the Oxford Lake area. It is inferred from Figure 65 that during the M_2 metamorphism the geothermal gradient was significantly higher than during the M_1 metamorphism. The diagnostic minerals involved (plagioclase, amphibole and chlorite) are common and omnipresent in the relatively calcium-rich and aluminum-poor rocks of the greenstone belt, whereas alumina-rich phases are rare and therefore unsuitable for diagnostic purposes in this area.

STRUCTURE

Introduction

All units, except the diabase and gabbro dykes of unit 13 have been deformed. The intensity of deformation was highly variable. It was generally weak in central Oxford Lake, in the area between Kwaykwaychi Bay, Semple Bay, Eight Mile Point, Jackson Bay, Pakitahokansik and eastern Carghill Island. Several domains escaped significant deformation, e.g., the peninsula south of Semple Bay, which was affected by the lowest grade of metamorphism detected in the map area. Bedding planes and original structures are well preserved in such domains, since younger foliation was not pervasive. Pillows, however, are flattened into a consistent direction, parallel to the well-developed foliation in adjacent, more strongly deformed rocks.

Major folds with wavelengths of about 0.5 to 1 km are well developed in the rocks of the Oxford Lake Group, particularly in the eastern part of the map area. Generally these folds are subvertical or steeply overturned to the south, southwest and west.

On outcrop scale rocks of the Hayes River Group and the Oxford Lake Group generally display a single foliation. Sporadic minor folding locally superimposed a younger foliation.

Quantitative structural analyses

Evidence for two separate orogenies, an older predating the deposition of the Oxford Lake Group and a younger postdating that event, was discussed earlier, based on the existence of an angular unconformity, pre-Oxford Lake Group mylonites and contrasting metamorphic histories for the Hayes River Group and the Oxford Lake Group. However, a quantitative analysis of structural data (Figs. 68 and 69) yields no evidence for two distinct deformations in the Hayes River Group, or for a phase of deformation in the Hayes River Group that did not affect the younger Oxford Lake Group. Bedding planes, foliations and attitudes of folds in the Hayes River and Oxford Lake Groups are parallel on a regional scale.

Figure 68 displays pi-diagrams of foliations measured in all units. All domains and units yield well-defined pi-maxima. In most instances the pi-maxima nearly coincide with the maxima of the plots of the bedding planes. This could be interpreted that the main foliation (S_m) was generated during the development of the steeply dipping synclinorium of the Hayes River Group and the Oxford Lake Group. However, such an interpretation does not support a polydeformational history. The assumption that structures related to the pre-Oxford Lake Group deformation were either poorly developed, or erased by the post-Oxford Lake Group deformation seems unfounded since the pre-Oxford Lake Group (M_1) metamorphic zonation is preserved despite the younger post-Oxford Lake Group orogenic overprint. Because of these uncertainties as to the correlation of structural elements the regional foliation and major folds have been assigned arbitrarily to event D_m. D_m structures in the Oxford Lake Group are associated with metamorphic event M_2. Table 8 lists the order of tectonic and metamorphic events using D_m as an arbitrary base.

Large-scale structures

During the major folding event (D_m) the Hayes River Group monoclines and the strata of the Oxford Lake Group were deformed into subvertical folds resulting in the formation of large-scale westerly- to northwesterly-trending regional structures such as the flexure in the Hayes River Group monocline in the Back Lake-eastern Semple River area and the Oxford Lake Group synclinorium. These structures (F_m) with over 15 km wavelengths were generated contemporaneously with folds of shorter wavelength (0.5 to 1 km) in the eastern Oxford Lake-Jackson Bay area of the Oxford Lake Group synclinorium. The northerly-, northwesterly- and westerly-trending F_m folds of the Oxford Lake Group are isoclinal, with subvertical and southerly- to westerly-dipping axial planes.

Minor and late-stage folding

Similar Z- and S-shaped parasitic folds of the F_m generation are superimposed on the bedding planes in rocks of the Hayes River and Oxford Lake Groups.

A unique structure underlies the area between Eight Mile Point and Jackson Bay, where major structures (F_m) have been refolded along east-trending axes, which are related to left-lateral movements along the fault system that runs through the channel between Semple Bay and Eight Mile Point. These large-scale drag folds ($F_m + 2$, Table 8) have 0.5 to 1 km wavelengths. The geological map indicates that the northwest-trending F_m structures in the Oxford House area gradually change into west-trending F_m structures in the Eight Mile Point area, where they are subparallel to the younger ($F_m + 2$) structures to the south.

Moderately steep, westerly to southwesterly-plunging folds superimposed on the synclinorial structure (F_m) of the Oxford Lake Group at Kisetpiskanak Island and Thomsen Island belong to the ($F_m + 2$) generation. They are thought to be related to the sinistral fault movements $D_m + 2$) in southern Oxford Lake.

A set of minor Z and S folds ($F_m + 2$) with axial planes ($S_m + 2$) subparallel to the main foliation (S_m) were recognized in all domains and units except in Units 11, 12 and 13. Their style varies from near-similar to chevron-type. Stereographic projections of the fold axes display partial girdles with consistent orientation throughout the map area (Fig. 69) suggesting this set has formed late during the structural history, possibly in association with fault movements. The minor folds are generally irregularly distributed. They are abundant at the western end of the Carrot River greenstone belt and on Thomsen Island.

Faults

Most major faults and shear belts that transect the Oxford Lake-Carrot River greenstone belt trend in an easterly to northeasterly direction. They underlie prominent lineaments, and to a large degree they define the outlines of the greenstone belts. The faults are likely wrench faults with subordinate vertical movements. Several closely spaced faults forming a shear belt occur in the areas around High Rock Island, Lynx Bay and along Carrot River. Most fault trends are extrapolated on the map. Both right-lateral and left-lateral wrench faults have been documented.

Large-scale right-lateral movements ($D_m + 1$, Table 8) of the shear belts that underlie the Cooney Lake-Lynx Bay area were described earlier. The Carrot River fault, which runs from just north of Cooney Lake towards the west end of the Carrot River belt seems to be part of this fault system, which developed during event $D_m + 1$. The large S-shaped outline of the supracrustal belt of the eastern Carrot River, Carrot Bay and Lynx Bay area may be the result of the large-scale dextral movements, during which the Carrot River fault acted as a detachment plane along which the central part of the Carrot River (Wakehao and Brogden Lakes) was forced to buckle in a northerly direction.

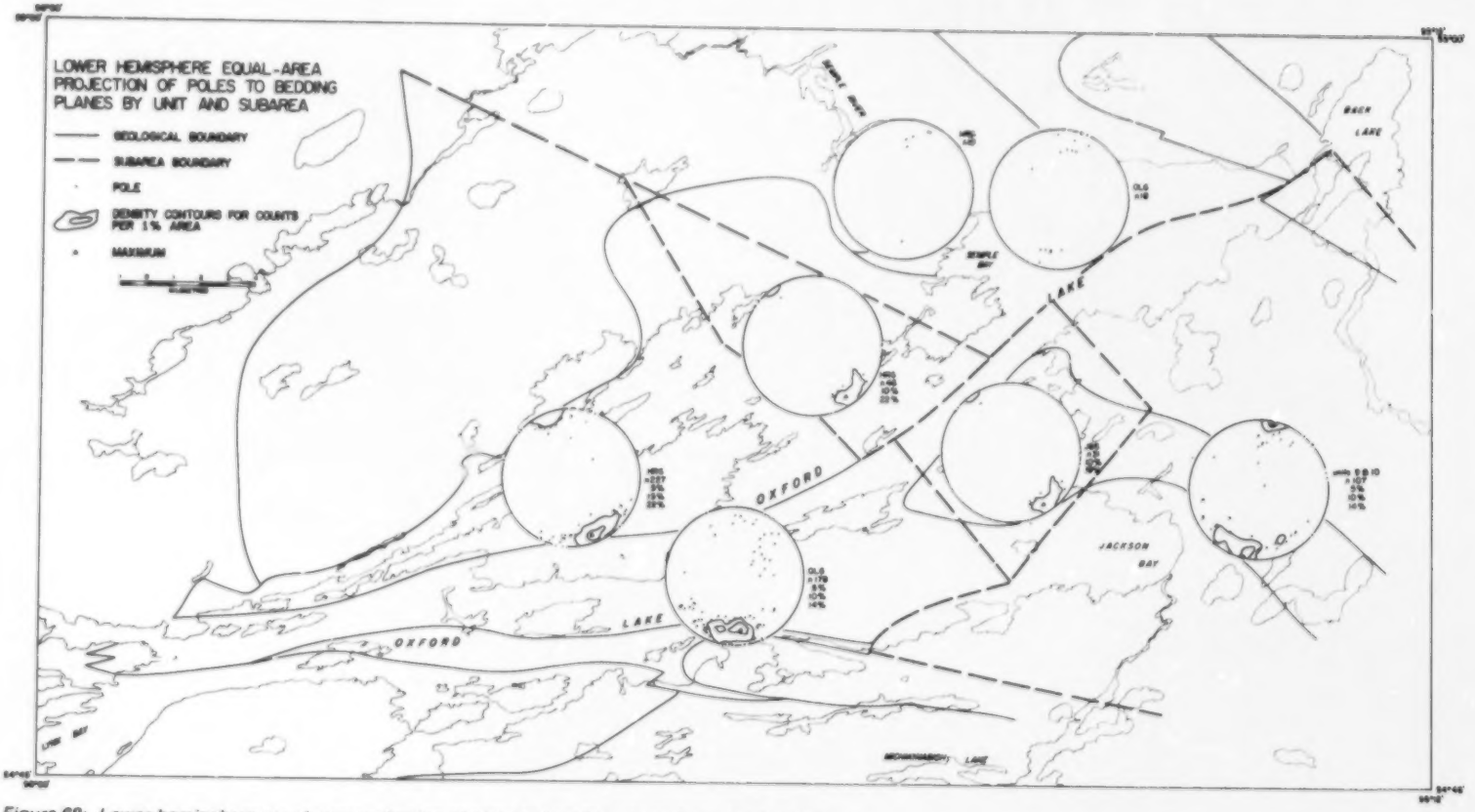


Figure 68: Lower hemisphere equal-area projection of poles to bedding planes by unit and subarea.

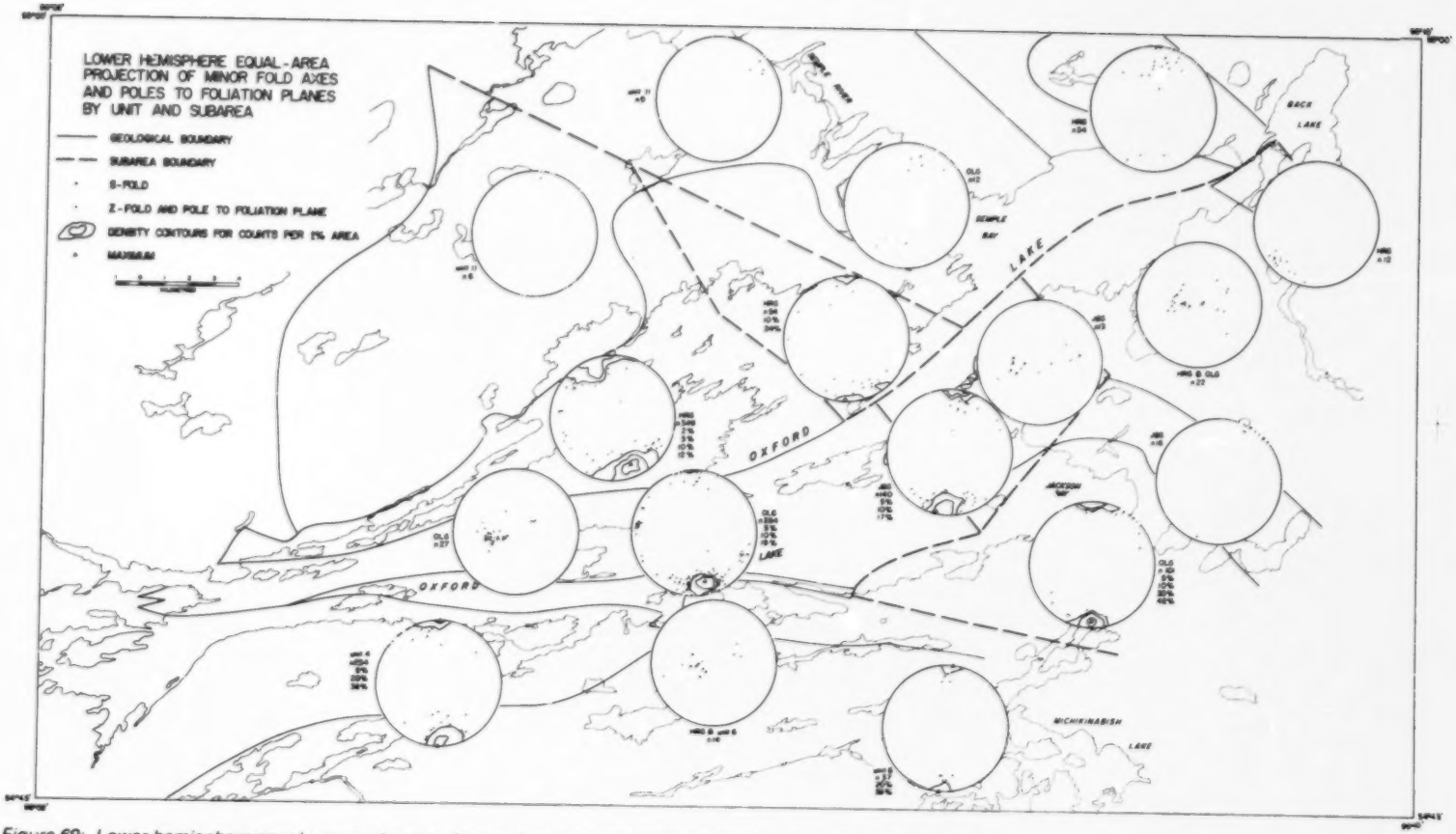


Figure 69: Lower hemisphere equal-area projection of minor fold-axes and poles to foliation planes by unit and subarea.

Dextral faults ($D_m + 1$) were postdated by sinistral movements ($D_m + 2$) in the Lynx Bay area. Sinistral movements preferentially occurred along the southern margin of the Oxford Lake greenstone belt. The two major westerly-trending wrench faults that are inferred south of Kisetpiskanak Island, enclosing High Rock Island, are extensions of the wrench fault in Lynx Bay and can be extrapolated towards Cat Eye Bay. A left-lateral displacement of approximately 15 km and a right-lateral movement of about 7 km along the northerly and southerly wrench faults, respectively, were estimated by correlating rock units and metamorphic zones across the faults.

Sinistral movements between Semple Bay and Eight Mile Point, discussed above, may join up with the fault that bisects Carghill Island and can be traced towards Carrot Bay.

CONCLUSIONS

Basement enigma

Ever since geological investigations started in the greenstone belt terrain of northeastern Manitoba, a pre-greenstone belt basement was envisaged (Horwood, 1935; Bell, 1971). The term 'basement' is defined*: a series of metamorphic and igneous rocks, generally with complex structure, unconformably overlain by sedimentary and volcanic** strata. This definition implies that the effects of an orogenic cycle older than the deposition of the greenstones are intrinsic features of a basement complex. During the course of this study no evidence was found for the existence of such a basement for the Oxford Lake-Carrot River greenstone belt. The basement problem in the northwestern Superior Province is further discussed in Hubregtse (1980).

Nature and tectonic environment of the Hayes River Group

The Hayes River Group consists of at least six successive basalt-rhyolite sequences (Hubregtse, 1976, 1978). It is envisaged that the felsic pyroclastic and flow rocks formed rather isolated culminations on the mainly basaltic strata of the lower part of each cycle. The chemistry of the volcanic rocks of the Hayes River Group suggests an ocean floor affinity rather than an island arc tectonic environment (Hubregtse, 1976, 1978). The Archean basalts and modern ocean floor basalts have similar quenched phases and microphenocrysts. The depository of the Hayes River Group may have reached abyssal depths during certain stages of the deposition of the Hayes River Group, but near the completion of each cycle, water levels around the felsic domes must have been shallow, since crossbedded and well sorted sediments are generally associated with the rhyolitic upper strata of the volcanic cycles. This view is supported by the presence of sporadic intraformational oligomictic conglomerates derived from mafic volcanic Hayes River Group rocks. Therefore, a direct comparison between the Hayes River Group and an ocean floor environment does not seem to be valid.

Another discrepancy between the lower volcanic sections of greenstone belts and modern ophiolites is the absence of a sheeted dyke complex in the former and the rarity of high temperature ultramafic extrusions (such as the High Rock Lake peridotite flow). The question arises whether a modern analogue for Archean greenstone belts exists. It has been argued that the extrusion of high temperature ultramafic liquids was possibly due to a higher geothermal gradient in the Archean (Hawkesworth and O'Nions, 1977). Tarney et al. (1976) attributed the absence of sheeted diabase complexes in Archean greenstone belts to the same effect.

Hawkesworth and O'Nions (1977) argue that Phanerozoic magnesian-rich rocks were extruded in rifting environments, and therefore Archean ultramafic eruptives may have been generated in a similar environment. They point out that the rock chemistry of Rhodesian and South African greenstone belts is reconcilable with a rifting model rather than a modern island arc environment. Tarney et al. (1976) modelled the formation of Archean greenstone belts after the formation and closures of a Tertiary back-arc marginal basin in southern Chile, essentially a rifting environment. This model is attractive because it explains the presence of newly-formed oceanic crust not overlying sialic crust but positioned adjacent to and occasionally overlying older sialic crust. A basement-cover relationship in the Rhodesian craton has been described (Bickle et al. 1975; Hawkesworth et al. 1975), but not convincingly from the Superior Province of the Canadian Shield as yet.

The nature and composition of the volcano-sedimentary sequences overlying the sheeted diabase complex of the marginal basin (Tarney et al. 1976) is very similar to the supracrustal rocks of the Hayes River Group, as it comprises pillowed basalts and sialic volcanics overlain by sequences of volcanogenic greywacke with thin interbedded chert and mudstone. The greywackes may be interbedded with andesite lavas, tuffs, volcanic breccias and conglomerate. The latter andesitic lavas are thought to have been derived from an andesitic volcano of which now only the root is exposed, represented by a granodiorite batholith that separated the marginal basin from the ocean. The tonalites and the intermediate to felsic volcanics of Lynx Bay (Units 4, 5 and 6 at Oxford Lake) may represent the ancient counterparts of the granodiorite batholith and subsequent syntectonic tonalites of the marginal basin model. Although there are striking similarities, it should be stressed that the marginal basin model required subduction and implies the contemporaneous existence of an island arc environment, for which so far no evidence has been found (Hubregtse, 1976 and 1978).

Nature and tectonic environment of the Oxford Lake Group

Since an orogenic phase preceded the deposition of the Oxford Lake Group, the Hayes River Group and the Bayly Lake Complex formed a basement for the Oxford Lake Group. Its deposition must have taken place shortly after the termination of the older orogenic cycle based on radiometric ages available for the Hayes River Group (2.7 Ga) and the base of the Oxford Lake Group (2.7 Ga).

It is inferred from the distribution of primary sedimentary features and the thickness of Oxford Lake Group conglomerate layers that the synclinorial sequence between Eight Mile Point and Forestry Point represents the deeper part of the Oxford Lake Group basin, in contrast to the zone directly south and west of the Oxford Lake volcanic subgroup, where shallow water conditions were prevailing. The deeper part of the basin displays an unconformity on a regional scale with the Hayes River Group. It is flanked, and possibly underlain, by volcanic rocks of the volcanic subgroup of the Oxford Lake Group and subsequently intruded by an early- to syn-orogenic granodiorite. The rocks of the volcanic subgroup are potassium-rich and have the chemical properties of a shoshonitic association (Hubregtse, 1976, 1978). Joplin (1968) concluded that rocks of the shoshonitic association have been recorded only within continental regions and along continental margins. Thus, the chemical characteristics of the volcanic subgroup lend support to the view that the crustal conditions changed drastically after the formation of the Hayes River Group. The shoshonitic rocks of the Oxford Lake Group are interpreted to be related to the formation of deep-reaching fractures during the deposition of at least part of the Oxford Lake Group on the newly-created continental-type crust. A graben-like structure is envisaged for the deeper part of the Oxford Lake Group basin.

* Dictionary of Geological Terms (1962).

** "volcanic" added by author.

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MAPS NOT

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